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A quarterly paper devoted to the sugar interests of Hawaii and issued by the Experiment Station for circulation among the plantations of the Hawaiian Sugar Planters' Association.

In This Issue:

Phosphate Deficiency:

The photograph reproduced on the cover shows the early, greatly stimulated root and shoot development of sugar cane which results from the application of a phosphate fertilizer with the seed at the time of planting. Two other photographs appearing hereafter, verify and emphasize the fact that a lack of stooling is a rather definite symptom of phosphate deficiency, when the green color of the leaves indicates a sufficiency of nitrogen.

Variation in the Nitrogen Content of Irrigation Water Carrying Dissolved Nitrogen Fertilizer:

Recent observations of a certain degree of carelessness by operators applying dissolved nitrogen fertilizers in the irrigation water make timely the presentation of the results of a study which brings out the variations in the nitrogen content of such irrigation waters, and suggests our more careful consideration of the approved and more reliable procedure.

Better Planning for Field Experiments With Fertilizers:

Anticipating still further the practical difficulties in the handling of large field experiments conducted on a plantation scale, we present a timely discussion concerned with some of the considerations that need our best thought and attention when planning the fewer and better field experiments with fertilizers that will probably follow. The avoidance of faulty designs, the guidance from rapid chemical and Mitscherlich soil analyses, the use of preferred plans, and constant efforts to reduce the experimental error are becoming more and more important factors of our field experimental technique.

Observations and Impressions in East Africa:

Added to the glamour of being among the last outposts of the primitive, the countries visited by the author of this article have the importance of harboring rich and as yet very incompletely developed sources of raw materials. It is this last named distinction, which is of little interest to the naturalist, that is most likely to focus the attention of the world on East Africa on frequent occasions during the next few years.

Soil and Plant Material Analyses by Rapid Chemical Methods—II:

This article is a second contribution to "Soil and Plant Material Analyses by Rapid Chemical Methods," the first having been published in the *Record* in 1936.

Additional rapid methods of analysis are described which were developed to augment research by plantation and Experiment Station agriculturists and chemists.

Specifications are included for the construction of a laboratory suited to conducting R.C.M. studies. Formulae and instructions are presented for the preparation of reagents used in the determinations described.

The subject of color standards is discussed in some detail.

Phosphate Deficiency

The value of phosphoric acid in promoting an early and vigorous root and top growth, and in encouraging adequate stooling of grains and grasses has been definitely established. In the accompanying photographs we offer contrasts that make it unnecessary to describe further symptoms of phosphate deficiency on sugar cane.

The illustration on the cover of this issue shows (at the left) 2 single-eye seed pieces of H 109 cane that were planted in a phosphate-deficient soil and removed for photographing at the age of six weeks, and (at the right) 2 comparable seed pieces planted in the same soil but which had been fertilized with a phosphate fertilizer at the time when the seed was planted.

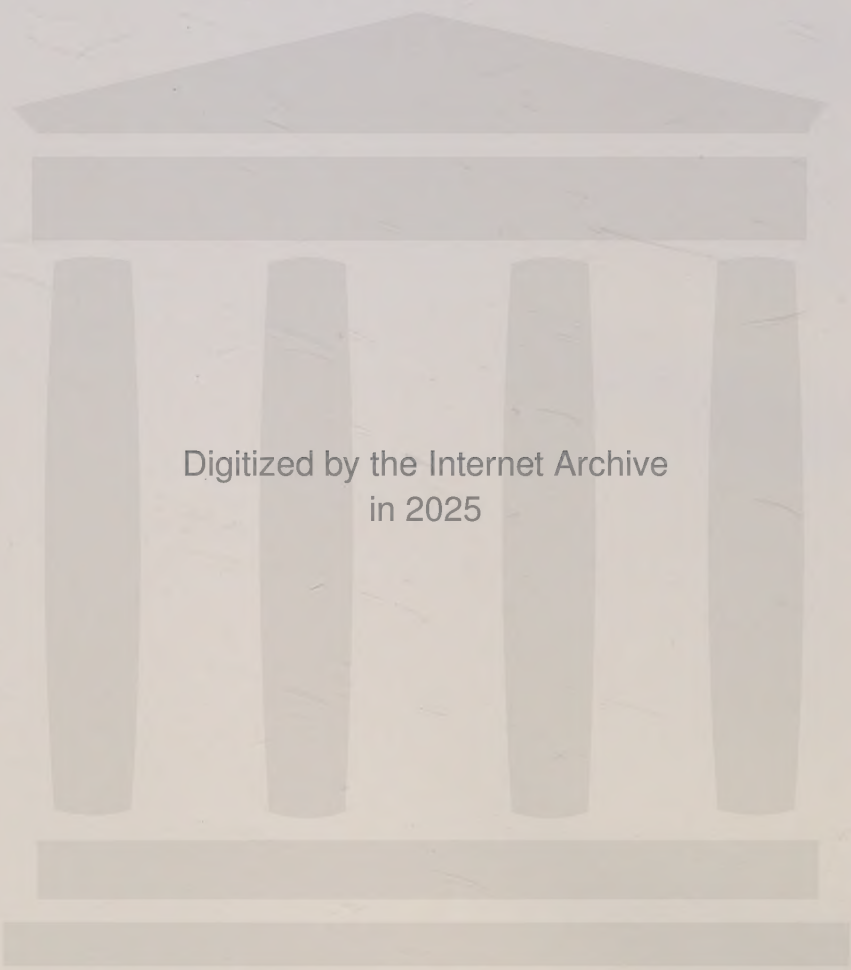
Fig. 1 shows H 109 cane growing in this same soil. The original stand in each lysimeter was secured from four eyes. In the pot marked "1—No P_2O_5" there has been an entire absence of stooling as well as a greatly inferior top growth, while in the pot marked "2—Super" the original stand has doubled and top growth has been quite satisfactory.

Fig. 2 shows another series of H 109 cane growing in small pots containing a "low phosphate" soil. The four original stalks that were established in the pot at the right are still there, but they have never stooled-out nor made much growth; they are merely existing in this soil which has not been fertilized with phosphate. In the center pot the same soil was fertilized with phosphate before the four shoots were planted, and the effect of this phosphate fertilization is visibly shown by the abundant stooling and growth which the cane has made. In the left-hand pot, the cane growth and absence of stooling was similar to that in the right-hand pot up to the age of 7 months; phosphate fertilizer was then applied and 3 months later the photograph was taken. This fertilization resulted in the greatly stimulated stooling and growth that is indicated, and although not equal to the development of the cane in the central pot, the phosphate deficiency symptoms (as shown at the right) are fast disappearing.

R. J. B.

Fig. 1. Comparative growth and stooling of sugar cane grown with phosphate fertilizer (No. 2) and without phosphate fertilizer (No. 1).

Fig. 2. Cane growth and development; pots right to left respectively: without phosphate, with phosphate from time of planting, and with phosphate application delayed for seven months after planting.



Variation in the Nitrogen Content of Irrigation Water Carrying Dissolved Nitrogen Fertilizer

By R. J. Borden and K. H. Berg

In *The Hawaiian Planters' Monthly* for February 1902, page 100, we find perhaps our earliest reference to the application of a soluble fertilizer in the irrigation water for sugar cane. J. T. Crawley who writes of a method of applying nitrate of soda *devised* and used by Manager W. F. Pogue, of Kihei Plantation, in 1901, quotes Mr. Pogue as follows:

> . . . I have just finished fertilizing some 600-odd acres with nitrate dissolved in water and applied in the irrigation. The form of application was as follows: Dilute one bag of nitrate of soda in one barrel containing 50 gallons of water, one pail of this solution is added to four pails of water, or in that proportion; in another barrel a hose bibb in the bottom of the last barrel discharges the diluted solution into a tub which is kept filled to a given mark, from the tub mixture flows in an exact amount all day into the main irrigation ditch. The outlet of the tub is fixed, and cannot be opened or closed by the laborer doing the work. Strainers are used on the tub and diluting barrel. . . . . It seems to me that any soluble fertilizers can be applied much more evenly and certainly very much cheaper than in the ordinary method [application by hand]. It also seems to me that . . . . the applications could be made in small doses as the cane needs it. . . . .

Commenting on this method used by Mr. Pogue, C. F. Eckart states:

> As the barrel from which the nitrate solution is discharged into the main ditch is kept at a constant level, an even pressure and discharge is obtained which would guarantee a regular and unchanging admixture of nitrate solution and irrigation water.

In his bulletin "The Irrigation of Sugar Cane in Hawaii," W. P. Alexander in 1923 gave us an excellent photograph and description of the procedure, of applying fertilizer in the irrigation water, that was then in use at Ewa Plantation Company. This is reproduced here as Fig. 1.

In more recent years, it has been observed that some operators have been letting the fertilizer solution run directly into the irrigation ditch from the barrel of mixed solution, without using the intermediary tub with its solution kept at a fixed level. Such a procedure is shown in Fig. 2 and the results of a recent study* which we have made indicate that this method may be quite unreliable for, unless extreme care is exercised, this method of distribution lends itself to considerable variability in the amount of solution flowing from the barrel, since the pressure head in the barrel is constantly diminishing.

To determine some measure of this variability that is likely to occur when nitrogen fertilizer is applied in water, a number of water samples were taken at 5-minute intervals at the heads of several cane lines. The samples were obtained in the ditch, well below the point where the nitrogen fertilizer solution was being added from a single barrel. Since the level ditch was on a one per cent grade, the flow of water therein was quite slow.

The technique of sampling was to collect each water sample by making 20 dips into the stream of running water with a small test-tube sampler at the point desired. The samples were taken in duplicate, i.e., two lines were sampled simultaneously.

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* Project A-105—No. 77.

Fig. 1

"Fertilizer being applied in irrigation water. This setup of barrels is the standard method of applying nitrogen in solution at Ewa Plantation Co. Its proper use insures a steady and even concentration of the chemicals entering the ditch water at all times. In barrel 1 the nitrate of soda or sulphate of ammonia crystals are completely dissolved. Barrels 2 and 3 are made up to a fixed solution; for example, one barrel per one bag of 100 lbs. From here the solution runs into tub 4, and is so regulated that it is kept at a constant level. The opening into the ditch is so set that a known amount of liquid will enter the ditch during a known time, provided the level in tub 4 is not changed. If the solution entered the ditch directly from barrel 2 or 3, the pressure would diminish as the barrel emptied, resulting in a varying rate of discharge, first a rapid stream and then a smaller. It would be possible for one to regulate this by changing the opening constantly. Such a procedure however, cannot be done accurately. Again in refilling the barrel the concentration of solution will not be uniform. That is the reason for having two barrels. When one is being emptied, the other can be filled. Using this method the costly nitrogen fertilizer can be applied very uniformly in the irrigation water."

Hence Nos. 1 and 1A are duplicates, as are Nos. 2 and 2A, etc., and since the duplicates generally agree well, it is indicated that the technique of obtaining the water samples was sufficiently accurate.

A study of four such series was made and the resultant analyses of the amounts of ammoniacal nitrogen contained in the successive 5-minute-interval water samples show some rather large variations (Table I). When it is considered that the field that was getting this water was supposedly at all times receiving a uniform application (50 lbs. per acre) of nitrogen from the ammonium sulphate solution, these large differences are not indicative of any great degree of uniformity in the nitrogen application.

TABLE I

Ammonia Nitrogen in Parts per Million.

Elapsed time of sampling	Test 1		Test 2		Test 3		Test 4	
	No. 1	No. 1A	No. 2	No. 2A	No. 3	No. 3A	No. 4	No. 4A
0	48	48	28	36	5	5	36	36
5 minutes	48	36	36	36	2	2	48	48
10 "	36	36	12	12	12	12	48	48
15 "	36	36	12	9	7	7	48	48
20 "	48	48	5	7	48	48	36	36
25 "	36	36	9	9	60	60	36	36
30 "	36	36	9	12	72	60	28	28
35 "	28	28	36	48	72	72	28	20

A further part of this study was concerned with an attempt to ascertain whether or not the first few lines of cane next to the barrel of fertilizer solution were receiving any less nitrogen than the other lines, because it was conceivable that in this slow-flowing ditch, the irrigation water and the fertilizer solution might not be well mixed until after the water had flowed for some distance. The results of 6 tests, which are given in Table II, are apparently contradictory.

TABLE II

Ammonia Nitrogen in Parts per Million.
Samples in 10 Adjacent Lines Taken Simultaneously.

Cane Line No.	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
1	9	96	100	36	3	12
2	9	96	60	9	28	20
3	7	180	60	12	28	20
4	7	96	60	36	36	28
5	15	180	60	28	48	36
6	15	96	60	48	36	36
7	28	180	60	28	48	36
8	20	140	60	48	48	36
9	20	140	36	28	60	36
10	20	100	60	36	48	36

Test No. 5 indicates that the first few lines nearest the barrel do not receive sufficient nitrogen, while Tests Nos. 6 and 7 would lead to a contrary conclusion. While Tests Nos. 8, 9, and 10 were being run, it was noticed (by using a dye with the fertilizer solution) that the position of the barrel on the ditch bank had an important effect on the amount of fertilizer going into the first few lines. The accompanying diagram indicates the position of the two barrels, "A" and "B," with respect to the cane lines being irrigated. (See Fig. 4.)

Tests Nos. 8 to 10 were taken while barrel "B" was being discharged. As a result, the first few lines seemed to contain generally less nitrogen than the succeeding lines. To probe this still further, additional tests were run while either barrel "A" or "B" was being discharged. These results are presented in Table III, and the figures apparently bear out the preceding observation: while barrel "A" was being discharged the concentration of nitrogen in the water samples taken simultaneously from the first 10 cane lines is practically equal; on the other hand, when barrel "B" was being emptied, the water from the first four lines showed less nitro-

Fig. 2. An Unreliable Procedure.

Fig. 3. An Approved and Reliable Procedure.

gen than samples from the succeeding ones. Incidentally, Tests Nos. 11 and 12 offer additional proof of the all-important influence of the pressure-head in the barrel upon the nitrogen concentration in the ditch: the last fourth of the barrel was discharging while those samples were being taken, and although the stream of fertilizer solution from the barrel outlet seemed to be of the same magnitude as from a full barrel, the analytical results show that the nitrogen in the ditch water was exceedingly low.

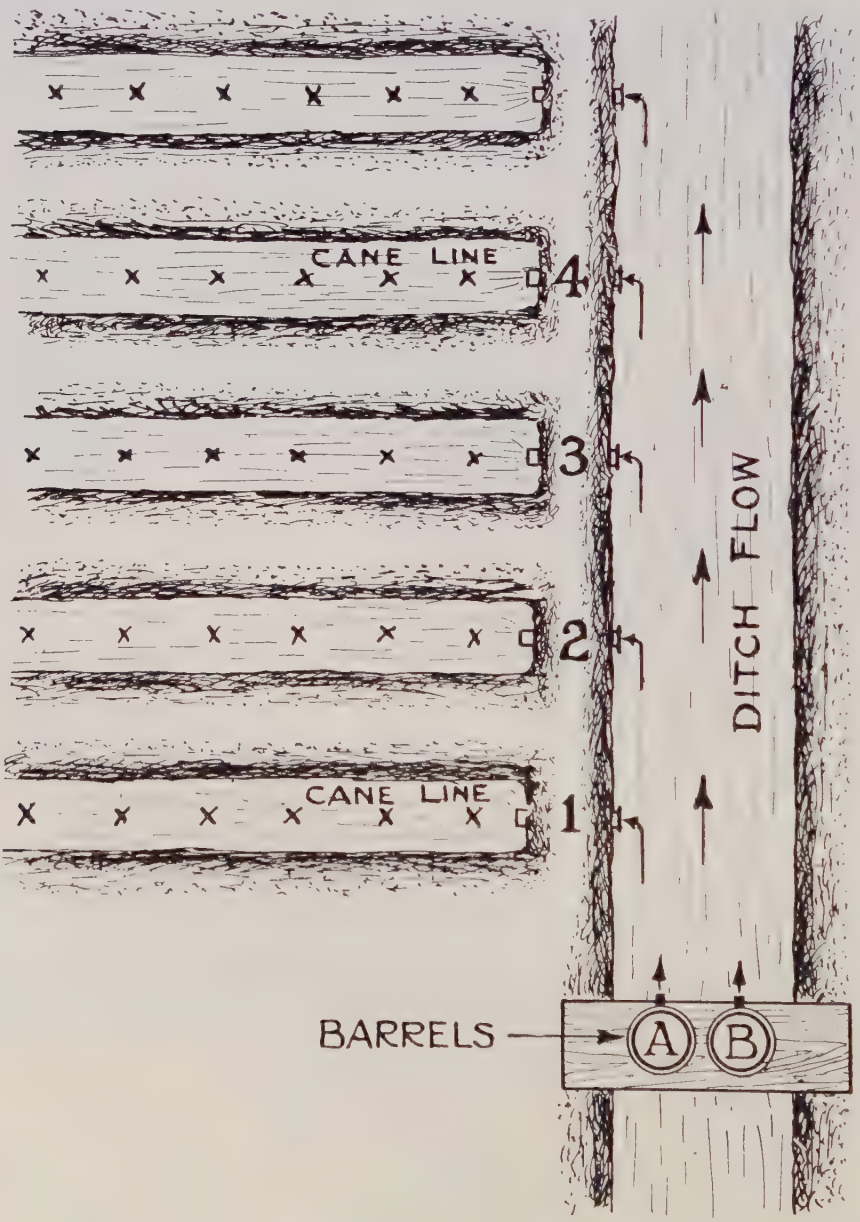

Fig. 4. Position of barrels of fertilizer solution with respect to cane rows being irrigated: "A" would be preferred to "B."

TABLE III

Ammonia Nitrogen in Parts per Million.
Sampled in 10 Adjacent Lines Simultaneously.

Cane Line	Barrel "A"		Barrel "B"	
	No. 11	No. 12	No. 13	No. 14
No. 1	7	15	1	1
2	7	7	20	15
3	9	12	20	12
4	7	7	20	20
5	9	7	36	36
6	7	7	36	36
7	7	7	36	36
8	7	5	48	36
9	9	7	48	36
10	7	7	48	36

When the procedure of delivering the fertilizer solution from the barrel to the ditch was changed from that shown in Fig. 2 to that shown in Fig. 3, and a constant head of solution was maintained in the final-discharge tub, an application of Chile potash nitrate (75 pounds of N and 70 pounds of K_2O per acre) was put on with a relatively even concentration throughout the first ten lines of cane, in two separate tests. These analytical results are given in Table IV.

TABLE IV

Cane Line	Test No. 15		Test No. 16	
	Parts per Million		Parts per Million	
	Nitrate Nitrogen	Potash	Nitrate Nitrogen	Potash
No. 1	90	90	80	90
2	90	90	90	90
3	90	80	90	80
4	90	80	80	90
5	60	75	90	80
6	90	90	90	90
7	80	90	90	80
8	90	90	90	90
9	90	75	90	90
10	90	80	90	90

The conclusions are perfectly obvious that, unless the better control and the approved technique (as shown in Figs. 1 and 3) for applying soluble fertilizer in the irrigation water are constantly used, we may well expect a very uneven distribution of such fertilizer material within the cane field, and from such an application a spotty cane growth can result.

Better Planning for Field Experiments With Fertilizers

By R. J. Borden

1—The Design

Statistical methods can help us not only to verify our opinion of the results from field tests but they can also guide us in our task of correctly designing an experiment. We can cite many instances wherein it has been found after the harvest results were secured that the particular experiment has shown "no differences," and a careful but belated examination of the design of the experiment has revealed an exceedingly small chance of detecting the effects which were likely to be met.

One of the first questions we must decide is, "What is the size of the difference between yields which we may be likely to detect in the experiment, if a difference exists?" It is quite possible that one treatment may be better than another but because of the random variation in the experiment, its advantage may not be detected. Also, how can we plan a test to assure a greater chance of detecting small differences when they do exist? An expenditure for an extra 50 pounds of nitrogen, or for an additional 100 pounds of phosphate or potash would be more than compensated for by the cash returns from an extra 2 tons of cane which might be secured (if the quality is not too greatly affected) and 2 tons of cane is certainly less than 5 per cent of our present-day average cane yield; so there is a real economic objective in seeking to measure such a small yield difference. Within the upper range of the treatment totals at which most of our fertilizer tests are run, yield differences of the nature of 10 per cent (7 tons on 70-ton cane) are seldom expected or found, for the law of diminishing returns is definitely effective and dominant. Hence we must prepare to measure the small differences that are definitely the result of the applied fertilizer treatments.

There are 3 ways in which this can be done: (1) We may use a less stringent level of significance, e.g., a probability of .05 (odds of 19 to 1) instead of a probability of .01 (odds of 99 to 1); (2) lower the probable error of a single plot by improving the experimental technique; and (3) increase the number of replications. The first method will increase the chance of detecting the advantage of "A" over "B" when it does exist, although it will also increase the possibility of a mistake when stating that "A" is better than "B." Many suggestions have been made available for ways to reduce the probable error of a single plot: plot arrangements for determination of positional variance; reduction of border effect; increased plot size; early correction of gaps in stands; closer supervision, and more adequate sampling. And we will need the increased number of replications to insure the reliability and to afford the means for a more nearly correct measure of the experimental error to compare with the so-called treatment error.

Table I has been prepared to assist the experimenter in planning his experiment and deciding whether the efficacy of the proposed test is sufficient.

To use this table, one will need to assume an expected per cent PEs for the experiment he is to install. An analysis of previous field experiments should give him

an approximate idea of what this figure may be. A study made in 1930 of all our cooperative field experiments showed an average PEs of 6.6 per cent, but we feel that this error has been somewhat reduced since that time, and we know that at some plantations it has recently been in the neighborhood of 3 to 4 per cent.

One must next "guess" at the size of the gain which may be expected from the proposed treatments, and here too, our past experience will be helpful. Generally speaking, we should seek to measure differences of the order of 5 per cent or less in our better fertilizer experiments.

Finally we should not be willing to accept a level of significance for our results, which is less than a probability of .05 (odds of 19 to 1).

TABLE I

Number of replications necessary to significantly measure differences (d) of the order of 10, 5, and 3 per cent when an approximate probable error for a single plot (PEs) can be expected.

Level of significance: P at .01
Odds 99 to 1

Formula $n = \left(\frac{3.8 \times PEs}{d} \right)^2$

Expected PEs	Difference to be Measured		
	10 Per cent	5 Per cent	3 Per cent
15 per cent	32	..	..
12 per cent	21	..	..
10 per cent	15	..	..
9 per cent	12	..	..
8 per cent	10	37	..
7 per cent	8	28	..
6 per cent	6	21	..
5 per cent	4	15	40
4 per cent	3	10	26
3 per cent	2	6	15

Level of significance: P at .05
Odds 19 to 1

Formula $n = \left(\frac{2.9 \times PEs}{d} \right)^2$

Expected PEs	Difference to be Measured		
	10 Per cent	5 Per cent	3 Per cent
15 per cent	19	..	..
12 per cent	13	..	..
10 per cent	9	34	..
9 per cent	7	27	..
8 per cent	6	22	..
7 per cent	5	17	..
6 per cent	4	13	34
5 per cent	3	9	24
4 per cent	2	6	15
3 per cent	1	3	9

An example: Assuming a PEs of 6.0 per cent for a proposed field experiment, and expecting to measure a difference of 5 per cent (from an expected 80-ton crop of cane) with odds of at least 19 to 1, we shall need to provide at least 13 replications. If we can conduct the test so as to reduce the PEs to 4.0 per cent, we can accomplish our objective with 6 replications; but if we wish to measure a 3 per cent yield difference from 9 replications we will need to reduce the PEs for the experiment to 3 per cent.

2—Phosphate Problems

In the planning of any field experiment that is concerned with a soil fertility problem, the rapid chemical method, the Mitscherlich test, and other indices of the supply of available nutrients in the soil should be made use of to more clearly determine the issue involved and to furnish the guide for the plan that is to be used.

Where the analytical indications point to a possible deficiency of phosphate, the chief issues involved are (1) how much to use, (2) what form is best, and (3) where and when to apply it for best results. Thus we have a choice of plans somewhat of the following nature:

Amounts of Phosphate:

Treatment Identity	Plans—Total Pounds P_2O_5 to be Applied									
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
X	0	0	0	0	0	0	0	0	150	100
A	200	100	150	100	75	150	100	200	200	200
B	..	200	300	200	150	200	200	400	250	300
C	..	..	..	300	225	250	600	600	300	400

Until the response to phosphate has been definitely established for the area where the test is to be placed, a zero phosphate series of plots is quite essential, and plans like Nos. 9 and 10 are inappropriate.

Because of the difficulty in securing reliable measurable effects of small variations of applied phosphate fertilizers in a field test, the successive increment differences should seldom be less than 100 pounds, and a plan like No. 4 is to be preferred to Nos. 5 or 6, while No. 10 is perhaps better than No. 9. Certainly No. 6 with only 2 treatments: A and B, or B and C, would be wholly unsatisfactory.

In view of the fact that experience has shown that it is desirable to use large increment differences (100 pounds), it is quite likely that the optimum amount will best be arrived at by an interpolation of the harvested yield data. Thus it will be preferable to have 4 treatments included in an "amounts" test in order that a more nearly accurate yield curve may be constructed for this interpolation, and so plan No. 4 will be preferred to Nos. 1, 2 or 3.

For those soils where we find a high phosphate fixation, plans Nos. 7 or 8 would get our preference; the "C" plots might be carried on after the first crop without additional phosphate, in order to study the possibility of a residual benefit from the heavy initial application. Only on a few phosphate-deficient soils where the phosphate fixation is negligible would we want to use a plan with 50 or 75 pounds increment differences, and then only if there was one series with zero phosphate, and another series receiving at least 150 pounds of phosphate for comparison.

When the preliminary studies of the analytical data indicate that a response to phosphate fertilizer is unlikely to be obtained, tests which are designed to determine an optimum amount are not in order; the issue involved now becomes one of simply checking our decision to omit phosphate from the fertilization, and of watching the trend of yields on areas where we continue to omit phosphate as compared with adjacent areas where it is being supplied, perhaps for insurance purposes. Thus the most suitable test becomes simply a response test and Plan No. 1 is to be preferred.

Forms of Phosphate:

Such tests should not be installed until a response to phosphate has been obtained, or its deficiency has been definitely indicated.

The amount of P_2O_5 at which the various forms of phosphate are to be compared should not be excessive since the relative efficiences may be masked if the least efficient form is supplied in such quantity as to enable it to supply the crop with its full phosphate requirement.

We would prefer Plan No. 11 to No. 12:

PLAN No. 11

Identity	Treatment
X	No P_2O_5
A	200lb P_2O_5 from superphosphate
B	200lb from rock phosphate

PLAN No. 12

Identity	Treatment
A	200lb P_2O_5 from superphosphate
B	200lb P_2O_5 from rock phosphate
C	200lb P_2O_5 from reverted phosphate

We would suggest consideration of Plan No. 13 where it is suspected that a calcium deficiency may cause a misinterpretation of the effect from a phosphate carrier like superphosphate or rock which both contain calcium:

PLAN No. 13

Identity	Treatment
X	No P_2O_5 or CaO
A	200lb P_2O_5 from ammonium phosphate
B	200lb P_2O_5 from superphosphate (or rock phosphate)
C	200lb P_2O_5 from ammonium phosphate plus the calcium equivalent of super (or rock)

Time of Application; Also Place of Application:

Unless it is suspected that these issues are reasons for a failure to secure a response, tests such as these should be installed only on soils where a real response has been secured. Both Plans Nos. 14 and 15, either with or without treatment "C" are good ones, but they would not be so satisfactory without treatment "X."

PLAN No. 14

Identity	Treatment
X	No P_2O_5
A	200lb P_2O_5 at planting
B	100lb P_2O_5 at planting, 100lb second season
C	100lb P_2O_5 at planting, 50lb at 3½ months, 50lb at 7 months

PLAN No. 15

Identity	Treatment
X	No P_2O_5
A	200lb P_2O_5 in off-bar (or subsoil) furrow
B	200lb P_2O_5 on top of stubble
C	200lb P_2O_5 broadcast between cane rows

General Considerations:

In any of these phosphate tests the amount of potash to be supplied, which will be similar for all treatments, will be quite reliably indicated by our R.C.M. tests and by former experience. It is only necessary that sufficient K_2O be supplied to make certain that it is not a limiting factor. Under conditions of heavy rainfall (150 inches), this may need to be at 250 to 300 pounds per acre, but on most of the irrigated lands, 200 pounds should be enough to insure against a potash deficiency. Similarly, nitrogen will be furnished at a total amount that is considered adequate for an optimum crop under the expected conditions.

Unless the time of application is a part of the issue being investigated, it is generally believed best that all phosphate which is to be used be applied as soon as

possible. This is especially desirable if the soil has a strong tendency to fix soluble phosphates at the surface, or if insoluble phosphates are to be used.

On fields which have in recent years had an application of filter cake by the plantation's usual procedure, we can expect to find considerable "spottiness" or a wide range in the amounts of available P_2O_5 in analyses of the soil samples from even small areas. As a general rule, however, most of such soil samples will not be phosphate deficient and hence "amounts" tests will not be suggested. This is quite fortunate because it will usually be extremely difficult to measure significant yield differences from varying amounts of phosphate fertilizer that might be applied to such fields. If, however, it is desirable to install phosphate tests of any nature under such conditions, we shall need to give attention to the installation of a considerably larger number of replications than we would ordinarily use, if we are to have any expectation of getting even just a fair answer from the test.

3—Potash Problems

As a general rule, only those cane land soils that have been formed under conditions of heavy rainfall, or which have been otherwise leached or very heavily cropped, are usually deficient in available potash. Under such conditions, after the rapid chemical analyses or the Mitscherlich test of a representative soil sample has indicated that we might expect a yield response to potash fertilizer, we may proceed to a determination of the optimum amounts, and the most efficient forms and methods of using potash fertilizers, and plans for such tests that are somewhat of the following nature will need our consideration.

Amounts of Potash:

	Plans—Total Pounds K_2O to be Applied												
Treatment	No. 1			No. 2		No. 3	No. 4	No. 5	No. 6	No. 7	No. 8	No. 9	No. 10
Identity	1a	1b	2a	2b	2c								
X	0	0	0	0	0	0	0	0	0	100	150	150	200
F	150	200	100	125	150	125	100	75	150	200	225	250	250
G	..	..	200	250	300	250	200	150	200	300	300	350	300
H	..	..	..	..	..	375	300	225	250	400	375	..	350

Plans Nos. 7, 8, 9, and 10, without zero potash plots, would not be used until an experiment on the area under test had definitely established a response to potash greater than the minimum amount proposed for the "X" plots.

In order to provide sufficient data for reliable interpolation, a 4-treatment plan like Nos. 3 or 4 would be preferred to a 2-treatment plan like No. 1, or to one of the suggested 3-treatment plans shown above as No. 2.

Results from Nos. 5 and 6 should be capable of reliable interpretation, providing the zero potash ("X") plots are included, but either plan used with only two of its treatments: F and G, or G and H, would not be satisfactory.

When a response up to 150 or 200 pounds of potash has been definitely obtained, Plans Nos. 7 and 8 may be used, both being preferred to No. 9 if sufficient area is available for an adequate number of replications for all 4 treatments; otherwise No. 9 would be the more desirable. Plan No. 10 will seldom be satisfactory since its amounts are pretty well up to a point where the law of diminishing returns for

potash will operate and cause only small yield differences that will be difficult to measure with any great degree of reliability.

When we have found a reliable and dependable indication that an ample supply of potash exists in the soil or irrigation water, which will make it unlikely that a response to supplementary potash fertilization can be secured, our Plan No. 1 will be all that is necessary to enable us to check our decision to omit potash fertilization and to watch for any adverse yield effect of such a decision.

Only when a response to potash has been obtained should we give serious consideration to comparative tests of the efficiency of various potash carriers ("forms"), or of issues dealing with time and methods of application. And in any tests of this nature, it will be wise to include a "zero" potash series of plots.

In all potash tests, we should be sure that phosphate will not prove a limiting growth factor. If there is any doubt about the phosphate requirement, it will be wiser to apply 150 to 300 pounds on low and high phosphate-fixing soils respectively than to leave an opening for criticism when the results are interpreted.

On fields where molasses has been applied for the benefit of the immediate crop, or when "mill water" is being used for irrigation, it will be extremely hard to secure consistent yields. Hence one should avoid plans wherein the expected yield differences from the various potash treatments are likely to be small ones; and it goes without saying that the number of replicates should be quite largely increased if field tests are to be installed on such conditions.

Although definite proof is lacking of a loss of potash from applied fertilizer by leaching from all soil types carrying a vigorously growing cane crop, we have measured such leaching from some soils and conditions. Hence it is undoubtedly a much safer procedure in all field experimental work to apply potash, where it is to be used, in single applications of perhaps not over 150 pounds K_2O per acre than in much larger amounts.

4—Nitrogen Problems

It is no simple matter to plan good nitrogen field experiments, for the issues involved are both numerous and complicated. In contrast to phosphate and potash experiments, a definite response to an application of nitrogen on cane is almost always secured, and the major problem becomes one of determining the optimum amount to be used. Since nitrogen is the most costly of our fertilizer ingredients its own economy must be considered; and since it can generally be shown that too much nitrogen results in "more cane with less sugar," a still further question of crop economy is involved.

As far as we know, there is no such build-up or residual carry-over in the soil of surplus applied nitrogen as there is of surplus phosphates, and hence we must consider the effects only upon the particular crop on which the nitrogen fertilizer is applied. Since the conditions under which successive crops are grown are scarcely ever identical, the effects from similar amounts of nitrogen fertilizer that may be applied are almost certain to be variable. Differences in crop length from 12 to 30 months will certainly affect the optimum amount of nitrogen that can be assimilated, but I do not believe that we have as yet proved whether this amount will be in the nature of a straight-line relationship like "A" in Fig. 1, or a relationship more like that of line "B."

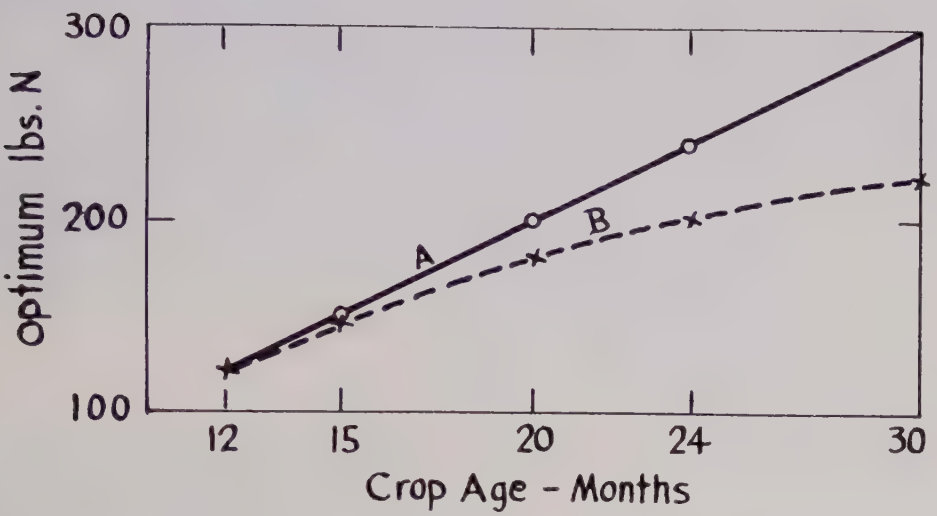

Fig. 1.

Differences in the uncontrollable yearly climatic conditions that frequently affect the cane yields as much as 20 to 30 tons will undoubtedly result in a difference in the economic utilization of a standard application of nitrogen fertilizer. Differences in the available supply of nitrogen, which will be greatly influenced by differences in soil moisture and in the amounts of organic matter and the conditions for its oxidation, will change the basic testing environment still further. Variety changes, perhaps changes in cultural practices, and quite likely changes in the time or the stage of development of the crop when the nitrogen fertilizer is applied will cause still more complication. Hence in our effort to find the optimum amount of nitrogen for our cane crops we must recognize these many factors that can influence such an optimum. Only by careful study of results from a series of well-planned nitrogen tests, conducted continuously so as to sample many cropping conditions, can we be assured that our interpretation of their results is most likely to be sound.

At the present time, we are not entirely sure just how to make use of R.C.M. or Mitscherlich analyses for available soil nitrogen, when planning field tests to secure an answer to the many nitrogen problems we may wish to investigate. Hence we are forced to intelligent reasoning and the utilization of what previous experience is available, meanwhile maintaining an open-mindedness towards many plans which are being used.

Amounts of Nitrogen:

In Fig. 2 we show two yield curves that illustrate the "law of diminishing returns." It is quite clear that the expected yield differences at the upper end of the curve between successive amounts of N are quite small as compared with those at the lower end. It becomes apparent at once that since the usual amounts of nitrogen which we supply in our N experiments are seldom less than 100 pounds, and that the optimum amount is usually to be found somewhere between 150 and 250 pounds, within which range the expected cane yield differences are quite small (and where

the negative relationship between cane yield and cane quality is likely to become a factor) we are going to have to design experiments that can be expected to measure these small yield differences with real significance.

We shall first need to consider the range of the nitrogen totals, the size of the increment (the nitrogen variable), and how and when this variable is to be supplied. We have some guidance from our past experience: Seldom have we found a crop that was not benefited by at least 75 pounds of total nitrogen but only in rare cases will the economic response exceed 300 pounds; nitrogen variables of less than 50 pounds (and we would consider 40 pounds as the absolute minimum), when these bring a nitrogen total above 150 pounds are exceedingly difficult to measure the effects of, and are to be discouraged.

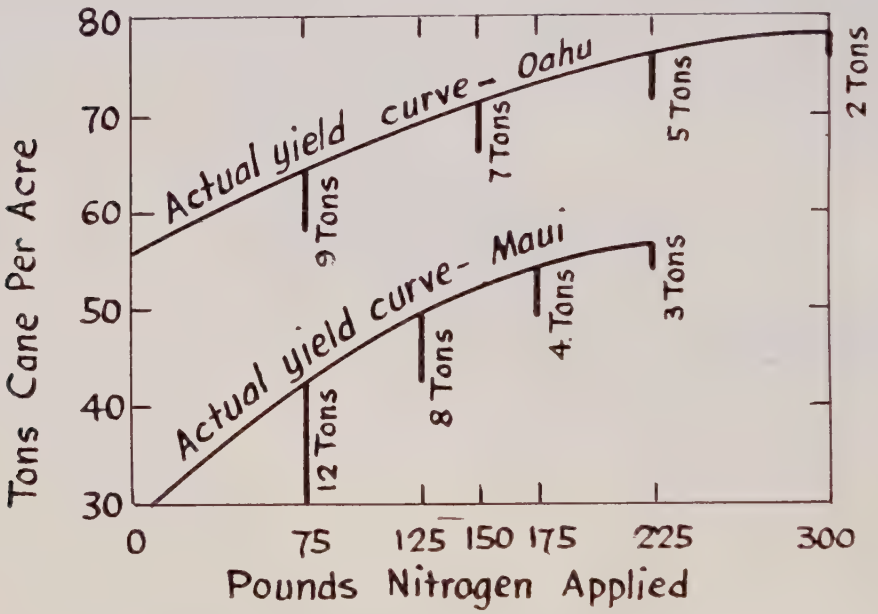

Fig. 2. Illustrating the law of diminishing returns.

The most debated point, for which there are many opinions but very few facts, is concerned with how and when the nitrogen variable is to be supplied. Our "Time of Application of Nitrogen" tests have not given us consistent results, so they cannot help us much. We have, however, some knowledge of certain facts which we believe may have some significance. Let us consider a few of them:

1. Analyses of the cane plant up to the time the crop is 3 months old have shown that only a very small amount of nitrogen has been taken up by this time; hence the need for supplementary dressings of N in the first few months is not very great. These same analyses have also indicated that the demand for nitrogen is especially heavy and that the uptake is very rapid from the time the cane "begins to make stalk" through the rest of its "first season."

2. Plant physiologists have indicated that there can be a translocation of absorbed nitrogen within the plant system, hence we might expect that surplus nitrogen

that is taken up during the "boom stage" would be available for second-season growth. We do not know whether or not such stored-up nitrogen has the same efficiency as a newly absorbed supply from a second-season application.

3. When a soluble nitrogen fertilizer is applied to a soil, it is made available not only to the cane but to the weeds and to all of the soil organisms as well. The greater this competition, the less nitrogen the cane crop gets at the time (and perhaps eventually also). But since it has been shown that the cane plant can take up nitrogen very rapidly when it has developed a large root system as compared with a root system which is only just being formed, we have knowledge that enables us to greatly reduce the length of this competitive period.

4. Ammonia nitrogen on an acid soil is just as subject to loss by leaching as a nitrate fertilizer. The loss of both forms by leaching is, however, quite negligible if the application is made to the crop after it has formed a well-developed root system.

And so we find quite a number of acceptable plans, none of which with our present knowledge can be given a preferential rating on other than personal opinion.

Usually the "Amounts of Nitrogen" tests carry three treatment variables and the objective is one of determining the reliability of the yield difference between (a) the mid amount and the low amount, and of (b) the high amount over the mid amount. When four variables are included, it is often possible to make a reliable interpolation and to secure the more nearly optimum amount therefrom.

The application of the nitrogen differential in water is to be discouraged, but if it is necessary then we must recognize that this method will be apt to greatly increase the experimental error and hence we shall need additional replications to offset (distribute) such error. Such added replicates of the treatments will also be called for when nitrogen tests are installed on land that has recently been treated with molasses or filter cake, since such treatments are also likely to increase the variation within a series of test plots.

R.C.M. and Mitscherlich analyses will indicate about how much P_2O_5 and K_2O should be supplied to all plots in the nitrogen test, so that neither P nor K will be a limiting growth factor.

Such plans as these should be quite satisfactorily adapted to most conditions:

PLANS—TOTAL POUNDS N

Plots	No. 1	No. 2	No. 3	No. 4	No. 5
A	75	100	125	120	160
B	125	150	175	180	200
C	175	200	225	240	240
D	225	250	275	300	...

Nos. 1, 2, 3, 4 may be used either with or without "A" or "D."

Herewith are eight examples of how the differential in Plan No. 2 (without Treatment A) might be applied.

Total pounds N split into 2 to 4 applications as indicated:

Plots	Total lb N	No. 2a	No. 2b	No. 2c	No. 2d
B	150	50–50–50	50–50–50	50–50–50–0	50–50–50–0
C	200	66–67–67	50–75–75	50–50–50–50	50–50–50–50
D	250	83–83–84	50–100–100	50–50–75–75	50–50–50–100

Plots	Total lb N	No. 2e	No. 2f	No. 2g	No. 2h
B	150	50–50–0–50	50–50–50	50–50–50	75–75–0
C	200	50–50–50–50	50–100–50	50–100–50	75–75–50
D	250	50–75–75–50	50–150–50	75–125–50	75–75–100

Next in importance to "Amounts of Nitrogen" will probably come "Time of Nitrogen" tests, and here many problems present themselves for better answers than we have at present, e. g.:

What proportion of the total N should be applied respectively in the first season and in the second-growth seasons; what proportions should be furnished before, during, and after the boom stage; how will these proportions be influenced by such factors as the (a) time of starting crop; (b) time of harvesting crop; (c) quality of the preceding crop; and (d) organic matter left by preceding crop.

Such a question as the relative effectiveness of 100 to 150 pounds of N applied in a single dose as compared with 2 or perhaps 3 doses, when given at different stages in the development of the crop has not had a satisfactory answer. Whether an extra 50 pounds of nitrogen is more effective in the early months, or during the boom stage, or at the beginning of the second season, is still a moot point, as also is the point of whether the season of the year or the stage of crop development is the dominating factor of "Time of Application of Nitrogen" tests.

In "Forms of Nitrogen" tests, the total amounts at which the various forms are compared should, if anything, be somewhat less than the optimum amount for the crop to be grown; unless this condition is provided, the least efficient form may be able to supply sufficient N for the crop and hence the comparative efficiencies will not be found. Perhaps the safest way is to include a series of check plots with the standard form at 50 to 75 pounds less than the amount at which the various carriers will be compared, e.g.:

X—N from ammonium sulphate with 125 pounds total N.
A—N from ammonium sulphate with 175 pounds total N.
B—N from nitrate of soda with 175 pounds total N.
C—N from urea with 175 pounds total N.

Little is known of the relative merits of nitrogen fertilizer placement for sugar cane. On cultivated lands, if the efficiency of the nitrogen when applied in the row-middle is equivalent to its application on the cane line, there is something to be gained through the former procedure.

Summary

Many of our field experiments still fail to answer clearly the question we have asked of them. Too often this failure is due to a faulty design that has been used, which under the conditions of the test has provided but little likelihood that a reliable answer could be secured. Especially when planning the design for the field experiment we do need to recognize that (1) the expected size of the uncontrolled variation (the probable error of the single plot yield), (2) the expected maximum amount of yield difference that will most probably be obtained from the applied treatments, and (3) the degree of significance (odds) which we are willing to accept as indicative of a real effect of this treatment, will all determine the number of replications that must be provided for in the layout.

Since the rapid chemical methods of testing soils have been made available and satisfactory qualitative answers to soil fertility problems are thereby more easily obtainable *before* the field test is actually installed, the main issues for the fertilizer field experiment will be concerned with (1) the determination of the optimum amounts, after indications of nutrient deficiency have been secured, and (2) the establishment of simple verification tests wherein the objective is to note any trend towards reduced yields caused by omitting some particular plant food, when the soil analyses have indicated a great sufficiency of same. For the former issue, plans that carry preferably four but not less than three treatment-variables are desirable; for the latter issue, a test with only two variables is sufficient.

Since many years of experience have indicated the difficulties that are generally concerned with measuring the effects of small increment differences on cane yields, certain minimum increments are suggested and acceptable plans for "Amounts" tests with phosphate, potash, and nitrogen are offered.

When the experiment is to be concerned with such issues as (1) the best form or carrier of a certain nutrient, (2) the optimum time for its application, or (3) the placement and methods of applying the fertilizer, it will be best to precede such test with one to determine definitely the need for the particular nutrient, unless such need is to be determined in conjunction with the other issue.

The analytical results from the rapid chemical methods of soil testing can be extremely useful in indicating the amounts of the other plant foods than the one being tested, that will need to be supplied so that they do not become the limiting growth factors.

Finally, it is economically sound that we plan field experiments that will measure relatively small yield differences between the applied treatments. If we depend too largely on a still further increase in the number of replications to do this, we will soon have an experiment that is quite impractical to handle. Hence it is apparent that our constant attention must be focused on those efforts to reduce the so-called "experimental error" which we know can be and has been reduced when the true and full value of reliable results is realized.

Impressions and Observations in East Africa

By F. A. Bianchi

It was my good fortune recently to take part, with Noel H. Krauss of Honolulu, in an expedition organized by the U. S. Department of Agriculture to search for enemies of the Mediterranean fruit fly. My services were lent for the purpose by the Experiment Station of the H.S.P.A. for a period of one year, and during that time, from September 1935 to October 1936, I spent eight months in four different countries of the African Continent. These included, besides Egypt, Sudan, Aden, and French Somaliland which were only touched in transit, the Mandated Territory of Tanganyika, the island Sultanate of Zanzibar, and the Colonies of Kenya and Uganda.

Of each of these countries I here offer those of my more salient impressions which I believe should prove of greatest interest to the readers of *The Hawaiian Planters' Record.*

Tanganyika

Our first stop in the territory once known as German East Africa, and our headquarters for the first two months of our trip, was the port of Tanga, six degrees south of the equator.

Founded by Germans on the site of an earlier Arab settlement, Tanga is situated on the edge of the Tanga Plains, a vast plateau which slopes gently upwards from the ocean to the easternmost range of the Usambara Mountains, more or less parallel to the coast on the N. E. corner of Tanganyika. Because the majority of its more substantial buildings face the completely enclosed bay, strung along unevenly on one side of a long street parallel to the shore, it welcomes the new arrival, while his boat still swings at anchor, with an impression of size that rapidly disappears upon closer contact with the reality of the case. As the ocean terminal of the important Tanga Railway and the center of a large sisal planting district, Tanga is nevertheless, one of the three or four principal towns of Tanganyika. As such it is amply furnished with fair hotels and well stocked stores and thus provided our expedition with headquarters which in comfort, if not in artificial entertainment of any sort, greatly exceeded our expectations.

Around the town and encroaching upon it in several places is found a thick fringe of coconut palms. Beyond this, the Tanga Plains are an almost uninterrupted extension of sisal plantations. Trees can be found only in scattered copses which mark either the sites of dwellings or the courses of streams. In the first case they are almost exclusively of introduced varieties and include for the most part fruit trees, mangoes, tropical almonds, cashews, citrus, papayas, sour sops, and others. In the second case, and that of small scattered areas unfavorable to agricultural development, the flora is remarkably rich and forms tangled and almost impenetrable masses of vegetation, among which even today are left remnants of valuable timber. Mvule, *Clorophora excelsa,* is at once the most common and the most useful of the

timber trees. Old timers averred that much of the land now given to the cultivation of sisal had been covered within their memory by flora of this type.

Prominent features of the landscape are spectacular specimens of *Adansonia digitata,* the baobab, which, as is often the case with the ceiba, *Ceiba pentandra,* in Central America, are occasionally left standing in cultivated areas. The baobabs with their bottle-shaped trunks are often remarkably large and handsome. Their seeds, closely packed within hard cases the size of a coconut, are embedded in a mealy pulp which is pleasant to the taste and from which can be extracted tartaric acid. Natives are fond of sucking them; and for some reason I did not ascertain, they also seem to have considerable attraction for an insect closely resembling in appearance, and almost rivalling in abundance, the well known box elder insect of the western United States.

Fringing the shores of the bay, wherever the slope of the land permits, is a belt of vegetation whose main component, *Rhyzophora mangle,* the mangrove, is well known in other tropical lands. Natives are often seen busily cutting and bundling the sticks of this plant for sale to Arab sailors who in Dhows—vessels of forbidding design—take the load to Arabia where the mangrove cortex is used in tanning and the sticks in the making of tents and firewood.

The larger game of the Tanga Plains, once probably as abundant as anywhere in Africa, has been almost exterminated, partly by man and partly by disease, but occasionally even now a lion, a leopard, a rhinoceros, or a buffalo is killed by some

Baobab tree, Tanga, Tanganyika.

week-end hunter within twenty or thirty miles of his home. Bushbuck, principally, and a number of other antelope species can still be easily obtained, and monkeys, mostly baboons and a long-tailed Cercopithecus species locally called Bastard Colobus, are very plentiful even in the immediate vicinity of dwellings where their wanton destruction of native gardens often assumes economic importance. Almost any afternoon walk is likely to bring one into the midst of a band of these remarkably tame animals. An African acquaintance of mine by imitating their peculiar chirping noises could walk up within arms length of them at any time.

Snakes, although I met only one, are said to be uncomfortably common everywhere, even within the town of Tanga itself. They include the dreaded black mamba, the puff adder, and an occasional python. On one occasion I barely missed seeing a python which had been found a few blocks from our hotel completely filling with its coils a freshly dug hole for a telephone pole. In their excitement the native electricians had failed to capture the animal, which, as nearly as their nervous description permitted me to judge, must have been 20 feet long.

Monitor lizards *(Varanus niloticus)* are occasionally found in the bush. Facially they resemble a python, but in the noise of their retreat through bush, no matter how impenetrable it may seem to a mere human, they show close kinship to a hurricane. They are said to be harmless, but having their five-foot length squirm between one's legs at a rate of twenty miles an hour, an experience I barely missed, might have painful consequences.

Small mammals like the cerval cat and mongoose are common, and particularly abundant and conspicuous in Tanga itself is a small lemur-like animal, *Bdeogale tenuis.* Often on moonlit nights dozens of these creatures can be heard chasing each other in wild gambols over the roofs of the town and their call, much like the wordless imprecations of an angered peacock, is on certain nights repeated with annoying persistence; otherwise, apart from the fact that they steal fruit, even entering open windows to do so, they seem to be harmless.

The insect fauna although not lacking interest for an entomologist might seem unexciting to the layman if it were not for the predominance among its more obvious constituents of Culicid and Anopheline mosquitoes. Coupled with a practically universal absence of screening, these pests constitute Tanga's only seriously annoying feature. To sit in the hotel lobby after dinner was a nerve racking performance for which, during most of our stay in Tanga, the majority of our fellow guests usually substituted the easier course of retiring early to bed. All beds in Africa are supplied with tent-like mosquito nets the edges of which can be tucked in under the mattress.

While investigating "ex officio" the sources of Tanga's mosquitoes I found that one of them was provided by the coconut plantations which surround the town. In contrast to the custom of natives in Hawaii and other countries, Africans usually dig permanent footholds into the coco palms; and each of these, worn in time by use and weathering, eventually becomes a receptacle for rain water ideally suited to the breeding of mosquitoes.

After dark, mosquito boots are worn generally by Europeans both men and women. Practically no one, however, of the people I met in Tanga had escaped the ravages of malaria. Among the natives, according to one of the local doctors, the incidence of the disease reaches practically one hundred per cent.

The fringe of coconut palms which surrounds Tanga. (Photograph by N. H. Krauss.)

Sisal fibre hung up on wires to be dried by the sun, near Tanga. (Photograph by N. H. Krauss.)

Flies are next to mosquitoes in the scale of "nuisance value." Species of Tabanus, Stomoxy, and Musca all exceed by far the reasonable limits of abundance to which a traveller becomes accustomed in other parts of the world; so much so that many natives, and some Europeans as well, practice the habit of always carrying a fly-chaser in their hand. This consists of some animal's hairy tail, and it is often provided with an elaborately artistic handle carved from wood or made of closely strung colored beads woven into a pattern.

Though it is scarce and I never saw it in Africa, *Scyphophorus acupunctatus,* a Rhyncophorid which has recently made its appearance in Hawaii, is of some importance to the sisal growers of Tanga. I was told that one single larva, if it bored sufficiently deep into the spindle, would cause cessation of growth and eventual death of the whole sisal plant.

The visitor in Tanga is struck by the pronounced scarcity of the larger domesticated animals. Climate and a number of stock diseases, including the well known Nagana, make the raising of cows and horses almost impossible. Of the former there is a small herd which supplies a limited quantity of poor quality milk to the European households of the town, but of the latter I saw not a single specimen anywhere in Tanganyika. Burros, also not very common, were sometimes seen taking the place of the horse.

Dogs in pleasant contrast to the case of some other tropical countries are also scarce. Disease is a factor in the reduction of their numbers, and in addition the possession of and contact with them are contrary to the tenets of the Mohammedan religion, to which most natives belong.

Chickens are raised by every native household and so are goats which take the place of the less hardy and completely absent sheep.

During the course of our stay in Tanga several visits were made by both members of our expedition to the East African Agricultural Experiment Station. This institution, well known through its scientific work, yet seldom visited because of its remoteness from the more frequented travel lanes of the world is known in East Africa as "Amani" from the native name of its location, and is situated on the very rim of the East Usambara Mountain some 2700 feet above sea level. Formerly there existed a narrow-gauge railroad to negotiate the 45 miles that separate the station from Tanga; but today, guide books to the contrary notwithstanding, that rail line has been dismantled and there is left only a regular dirt road which is likely not to be passable on extra-rainy days.

Although supported in part by direct contributions from the Tanganyika and other East African Governments, Amani is distinctly an Imperial institution entirely free administratively from local control. Its main purpose is the conduct of basic research in the problems of tropical agriculture such as is beyond the practical scope of the various colonial departments of agriculture.

On grounds that cover more than a thousand acres, a large part of which is still a practically virgin forest, the Station has a remarkably up-to-date scientific library and shop facilities that enable it to meet almost any demand in the line of scientific or domestic paraphernalia. It produces its own gas and electricity, and a considerable part of its food requirements, and it has been entirely responsible, of course, for the erection of the very solid and handsome buildings it occupies. These are

beautifully located in the midst of well kept gardens, and they are so extensive that they could easily accommodate a much larger staff than the ten men who now carry on their researches within their walls.

Mr. Kirpatrick, the Station Entomologist, was at the time of our visit very busy with the study of a remarkable Stylopid parasite of Antestia, a pentatomid bug which ranks first among the coffee pests of Tanganyika. We were told that the parasite was a chance discovery made by Mr. Kirpatrick during a visit to Arusha, a distant district, and that it was in several respects an extraordinary insect. Not the least extraordinary feature of it, in view of the fact that in the laboratory this Stylopid reproduced prolifically, was the fact that it had not been found earlier during the many years that coffee has been grown and studied in Arusha.

Agave amaniensis, Amani, Tanganyika. (Photograph by N. H. Krauss.)

Shortly before our visit the Amani Station had taken over the management of a neighboring coffee plantation of 8 or 10 thousand acres and it was, as an unprecedented activity in its history, undertaking the practical application of scientific methods to the culture of coffee. In this effort it was seriously handicapped by the nature of the soil in the region of the Usambara Mountains. Being extremely old geologically, this highly acid soil is unsuited to the requirements of coffee production. It is no wonder, therefore, according to W. Nowell, Director of Amani at the time of our visit, that one by one all the coffee plantations in the Usambaras, most of them founded before the war by Germans, have deteriorated to the point of bankruptcy, and that today one of the main objectives of the Station is to find suitable substitute crops for coffee. Tea, kapok, sisal, cinchona, and kueme nuts were being investigated for this purpose with varying degrees of success; but with the condition of the world's markets even as late as November of 1935 the prospects of these crops with the exception of sisal were not very promising.

Sisal, which during our stay in Tanganyika seemed to be enjoying its first prosperous season in many years, owes its success in part at least to the efforts of Amani. A new variety, hardier and more rapidly growing than the parent stock, had been developed in Amani from a sport and was being rapidly spread in most plantations. We were shown the original plot of the new variety in Amani and were struck by its apparent superiority. It is distinctly purplish, in contrast to the pure green of the mother stock, and is called *Agave amaniensis*.

Sugar held but a minor position among the varied interests of the Amani scientists; but we were shown a fair sized plot in which were growing, carefully tended, several varieties of recent introduction mostly I think from India. In connection with our visit to this plot, we were told that no large sugar cane plantation existed anywhere in Tanganyika, but that a newly founded concern either planned or had already begun the erection of a large mill. Rumor had it that this mill was to be brought from Java, having belonged to one of the Javanese concerns which did not weather the late depression; but my further travels in Africa led me away from Tanganyika before I could ascertain further developments of this ambitious project.

The native forest at Amani. (Photograph by N. H. Krauss.)

Our attention was drawn in Amani by the great abundance of introduced trees and plants; and the size of many of them brought to our minds the reminder that much, if not most, of what is now found in the Station owes its presence there to the original German founders of the institution rather than to the present English occupants. This thought struck me particularly on visiting a beautiful wooded nook referred to occasionally as "Zimmerman's Corner," where a great number of Aroids still remain to witness the interest which the last German Director of Amani took in the introduction of new varieties.

Strikingly conspicuous among introduced trees were a number of conifers. Rearing their spiky heads incongruously above a tangled mass of luxuriant tropical vegetation, these were said to have been planted by early German arrivals during a violent fit of nostalgia. But no similar reason could be attributed to the introduction of many other trees, among which I noticed very fine specimens of *Ficus nitida* and a goodly sized planting of Cedrelas of various species which, judging by their size, may have been some forty years old.

Not on the grounds of the Station but in an adjacent estate called "Nderema," I was greatly surprised to find camphor trees growing wild. I believe they were the regular Japanese camphor *(Cinnamomum camphora)* of commerce, and I was told that from a small plot planted by early immigrants they had now spread over, and thickly covered, a total area of some 200 acres. There was some talk of developing the industry in a small way, but I have heard of no further developments.

The fauna of Amani is, of course, very different from that of the Amani plains and the difference is characterized at once by the great abundance in Amani of the fantastic hornbill, *Bycanistes cristatus,* a large black and white bird with a strong, orange-colored beak almost the size of the bird's body. This enormous beak serves in the emission of sounds of nerve-racking raucousness and in the destruction of large quantities of forest fruits.

A large and handsome Colobus monkey with white markings on the face, back, and tail was easily found; and other animals, including several varieties of monkeys, duikers, bushbucks, and wild pigs were not scarce, but finding them was a matter of chance.

Snakes were considered plentiful by the natives; but the staff of the Station could report only one case of snake bite in many years and that not a fatal one.

Some 350 miles inland, east and slightly north from Tanga, the map of Africa shows two large volcanoes, Mt. Meru and Mt. Kilimanjaro, approximately 15,000 and 20,000 feet high respectively. Rising from the vast elevated plateau which extending south from Abyssinia is bounded on the west by the East African Rift Valley and constitutes the backbone of Tanganyika, these two volcanoes cradle on their southern slopes one of the rich coffee-growing areas of the world, and perhaps the most picturesque town in the Territory. In this town, Arusha, I spent late March and early April and, during a second short visit, the first days of June.

As the study of the fruit flies affecting coffee was my main concern in this region, I had occasion to see quite a bit of the industry and to learn something of the problems which it faces. The poor market then prevailing was, of course, the basic difficulty. Shortage of labor, however, was the handicap of which the planters most bitterly complained. Their product some of them explained enjoys preference

Scene near Arusha, Tanganyika. Mt. Meru in the background.

and is less affected by poor market conditions than other coffees, but even so, should the labor situation continue on the present trend, the day is not far distant when this region will not be able to supply even its limited share of the world's demand.

The method of working or "curing" coffee in Arusha is in some slight but important respects different than that followed elsewhere. Because flowering and ripening occur continuously during the fruiting season rather than at more or less definite intervals as often happens in other places, harvesting is necessarily a continuous activity which is carried on with unremitting intensity during the whole season. Harvesting is also, by choice, more selective than in other countries so that only fully ripe berries reach the mill. The milling process is, therefore, much simpler and less expensive in Arusha. The complicated system of flumes and settling tanks required in other places to separate and treat the berries according to their varying degrees of ripeness is reduced to a single tank where unsound berries, being lighter, float above the sound ones and are easily decanted. In some cases I was told even this process is eliminated and the coffee is carried directly from the field to the pulpers.

The vast drying platforms of concrete, on which in Central and South America coffee is daily spread out in the sun and raked over, are non-existent in Arusha. Their place is taken by large screen-bottomed trays, which, although requiring a considerable amount of handling, are said to result in a saving of time and labor.

Warriors of the Warusha tribe, allied to the Masai, Arusha.

The roads of Tanganyika are not always passable during the rainy season. On the road to Ngorongoro Crater.

In the field of Entomology my attention was repeatedly drawn to the damage by two pests which seemed particularly to worry the planters. One of these, the *Antestia sp.* to which I have already referred in connection with my visit to the Amani Experimental Station, seemed fairly well checked on the more progressive plantations through the methodical application of stomach poison sprays. The other, however, a Cerambycid of the genus Anthores, presented a problem for which no solution was yet in sight. Endemic on many hosts native in the region and with a life cycle of only one year, this insect is practically beyond eradication from the bush that everywhere encroaches upon the cultivated areas of Arusha. An inexhaustible supply exists, therefore, for the reinfestation of cleared areas, and it is exceedingly difficult and expensive to clear these in the first place. In coffee trees, insertion of paradichlorobenzene crystals into the tunnels of the larvae has been tried with only partial success, and so far no more efficient method of control has been devised than to have men pull the larvae out by means of a thin wire bent into a small hook.

In many "Shambas," as plantations are called in Tanganyika, a considerable proportion of the coffee trees were apparently suffering from a disease which had not been diagnosed and was causing great concern. Appearing first as a general discoloration of the foliage, every indication of the trouble sometimes disappeared within a few days, without further injury to the tree; but in most cases discoloration was quickly followed by complete wilting and prompt death of the whole plant. As practically no work had been done on this disease by the agricultural authorities of the region, and evidently none whatsoever by the planters themselves, it is quite possible that the damage observed was not due to a disease at all, strictly speaking, but to some other unsuspected agency. My suggestion that this agency might be the enormous population of scarab grubs found everywhere in the vicinity of Arusha was received with favor by several planters, and one in particular made efforts to secure a supply of white arsenic to apply to his fields. What success he had, if any, I have not heard, but having lately read an account of an attack on coffee in Java by larvae of Lachnosterna I am further inclined to believe that white grubs may have been the cause of the trouble in Arusha.*

Though situated in a zone extensively cultivated, Arusha lies within easy distance of vast plains where many of the larger African animals are still plentiful. In the course of fruit fly work and during walks or automobile rides which I took specifically for the purpose, I was able to approach closely and in some cases to photograph herds of zebra and giraffe and large flocks of ostriches. On two occasions I hunted lion; but although the beasts came near to our camp during the night and were plainly heard, I was unable to find them after the break of day. Failing to shoot lion, however, I was amply compensated during these two hunts by the sight of many jackals, hyenas, and literally hundreds of antelopes of many species, to say nothing of numerous minor animals and birds.

During one trip, longer than the others, I visited the famous Ngorongoro Crater about 100 miles west of Arusha. Some 15 miles in diameter and 2,000 feet below

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* de Fluiter—A preliminary communication regarding an investigation on an attack on coffee in Java by larvae of Lachnosterna, Review of Applied Entomology (Series A) Vol. 24, page 627, 1936.

the rim, the floor of this extinct crater is sometimes overcrowded with game of every species, as many as 50,000 gnus and zebras having been seen there at one time apart from smaller game; but during my visit no animals of any kind were in evidence. Dozens of hyenas and jackals, hundreds of antelopes which we saw on our way to the crater, and the one old rhinoceros bull which crossed the road fifty yards ahead of us, did not constitute in the opinion of my guide sufficient justification for the trip. It all lies in the point of view.

Zanzibar

Forced by the collapse of the A.A.A. and subsequent financial difficulties of the Department of Agriculture to remain much longer in Tanga than we originally intended, Mr. Krauss and I created interludes in our protracted stay by making short visits to the island of Zanzibar which lies only about 100 miles southwest of Tanga. Flying across, I remained on the island from December 3 to December 13, and was lucky to hit one of the drier periods of the year, as most of its sixty inches of rain supposedly falls during April and May. There were more or less light showers,

A typical street scene in the city of Zanzibar.

nevertheless, every day that I was there and the temperature and humidity seemed to be very much more disagreeable than they are in our own Hawaii during the hotter months.

An independent Sultanate before 1890, Zanzibar is now to all intents and purposes an English colonial possession. A Sultan still keeps his palaces and his motor cars; but his power gone, he has become only a voice in an Executive Council whose important member is really a British resident. The atmosphere of the old days remains, however, and wandering through cool labyrinths of narrow streets, amid turbaned and burnozed figures, with the muezzin call ringing in his ears, the visitor to Zanzibar may still feel closer to the past glories of the dead Arabian Empire than to the present day Africa. The population is not, nor has it ever been, predominantly Arab, but Swahili, and these natives of Zanzibar, however greatly the course of the centuries may have mixed their blood and changed their customs, are obviously rooted in the negroid strains of Africa. Their language enriched and modified by the Arabs, Portuguese, and other conquerors is today the lingua franca of Kenya, Tanganyika, and parts of Uganda. As it is spoken in Zanzibar, the liquid quality of its tones and the ease with which it can be learned constitute one of the pleasant features of the place.

The total population of the Sultanate, which includes also the Island of Pemba, very seldom visited by the casual traveler, numbers some 203,000 inhabitants, and of these the East Indian contingent, with some 14,000 members, is probably the most important racial group. Harder working than the Arabs and distinctly more able in the handling of money, the Hindus have gradually acquired much of the land and since the war are rapidly gaining control even of banking and the larger part of import and export business. The house of Karimjee-Ivanjee, landholders, wholesale exporters and importers of every kind of merchandise, is the best known business concern in Zanzibar and one of the most powerful in all of East Africa as well.

Agriculturally Zanzibar is so exclusively committed to the production of cloves and copra that but little land is left for the raising of other products. A wide variety of fruits and vegetables is grown in small plots and family gardens and evidently suffices to fill the local demand, but of the major staples everything is imported. Not even sugar or rice are now produced, although 100 years ago the former was an important item of the export trade.

The article of commerce which is known as cloves is produced outside of Zanzibar only in Sumatra, Penang, Malacca, and Madagascar; nowhere in quantity comparable to the production of Zanzibar. It consists of the dried flower buds of a tree, *Eugenia aromatica* of the Myrtaceae, the family of the well known Eucalypti. Thirty or forty feet in height, of elongate rather than spreading habit and with a great abundance of small, shiny, sweetly scented leaves, clove trees make plantations which rival in beauty the finest of gardens. Every bit as delicate, unfortunately, as its beauty might lead one to believe, the tree demands for satisfactory growth and production the deep, rich soil of the higher areas of the island, and it is only found there. Even there, under optimum available conditions, it exhibits a high degree of capriciousness and shows extraordinarily large variations of yearly output which have not yet been satisfactorily explained. The average annual yield for one tree

The clove crop of a small producer is dried by the sun on mats laid out in his backyard, Zanzibar. (Photograph by N. H. Krauss.)

is said to be around 4 or 5 pounds of the dried buds, but it may rise to 10 or 12 or fall to nothing without visible cause. As the industry has only recently come under the supervision of trained European agriculturists it is hoped that in the near future this peculiarity will be explained and perhaps avoided.

It is an interesting fact that the maximum age that can be attained by *Eugenia aromatica* is not known, nor the age at which a tree is most productive. No records were ever kept by the original Arab planters of Zanzibar that might today cast light upon these points, nor is it even known with certainty when nor whence the clove tree was originally introduced, although it is said to have been brought from Mauritius in the beginning of last century.

The harvest season of cloves lasts from July to February. In the days of the Arab domination it employed resident slaves, but today it depends on seasonal migration of labor from the mainland and often runs into the snag of labor shortage. With the steady rise of employment in the sisal and other industries of the mainland, it is feared that this snag will appear more and more often.

Picking of the buds is done by hand and foot, so to speak, for pickers climb directly on the trees without the aid of ladders or paraphernalia of any sort. The process requires considerable skill and agility, and it depends on the goodwill and carefulness of each picker to gather the buds at precisely that stage in their development when they have reached their full growth but have not yet started to open up into flower. This degree of maturity is discernible to the initiate through delicate color variations of the buds and produces the best and most expensive cloves which are used exclusively in the spice market. Immature, overdeveloped, or broken buds are only used in the distillation of essential oils and have to be separated from the perfect cloves by hand, a very laborious process which commences at the time of

picking and is only finished after the cloves have been spread out on mats and dried in the sun.

The process of drying in the sun, incidentally, is all that cloves undergo in Zanzibar, for distilleries, with the exception of one which had not been completed at the time of my visit, have never existed on the island. Distilling has always been done in England or India.

Although in 1872 all the clove trees on the island of Zanzibar were destroyed by a hurricane which freakishly missed the sister island of Pemba, all the plantations antedate by far the era of British influence. The industry, therefore, owes as yet but little to the modern science of agriculture, but rapid strides are being made by the Department of Agriculture in the scientific solution of its many problems and it is hoped that risks to the industry will eventually be reduced and its yields greatly increased.

In one of the series of experiments of the Department which particularly interested me, an endeavor was being made to determine the best leguminous cover crop for clove plantations, and three plants seemed to be giving promising results. These were *Calopogonium muscinoides, Tephrosia candida* (the Hawaiian *ahuhu*), and a species of Centrosema, all of which had been imported for the tests.

Although the clove industry of Zanzibar was more or less able to hold its own through the thick and thin of the late world depression, that was not the case with copra. In consequence of the depression, a large proportion of the palm lands is in the hands of the government to whom it accrued in lieu of defaulted taxes. Much against its wishes, therefore, the Department of Agriculture is actually in business and is forced to dedicate as much time to the commercial as to the scientific aspects of copra production. The government, I was told, was anxious to end this state of affairs, but it was only gradually succeeding in returning its lands to private ownership, although they were being disposed of on terms very favorable to the purchasers.

Kenya

Although I later returned for a shorter visit than my first one, I left Arusha the first time early in April and made my way to Nairobi, the capital of Kenya.

The trip by rail takes more than 24 hours and entails a prodigious amount of waiting and transferring at different stations. By car, however, it either takes eight hours if the road is dry, or it cannot be done at all when the road is wet. It was dry, fortunately, early in April, and my memories of the trip are pleasant. Traversing for about 200 miles an almost completely uninhabited plateau, the road leads one through rolling plains which in their physical features and in their enormous abundance of game recall our own western prairies in the days of the bison and the redskin. In Kenya, however, the grass is always green, and the variety of animals is incomparably greater than it ever was in America. Development of the ability to distinguish all the species would probably require many more weeks of close association with the "veldt" than fell to my lot, but the species I was able to recognize included by their common names, giraffe, eland, zebra, congoni, wildebeest, Grant's gazelle, Thompson's gazelle, duickerbuck, and bushbuck. Grant's and Thompson's gazelles seemed to be most abundant and could be seen almost any where along the road, singly, in couples, or in herds of hundreds. Very curiously,

most of these animals exhibit but slight alarm at the approach of an automobile, but a man on foot must spend hours in careful stalking to get near enough for a good photograph.

The grass cover of these plains is composed mainly of Rhodes grass, *Cloris gayana,* which harbors an enormous quantity of insects. Vicious ticks, grasshoppers of several species, and a small purplish Cantharid were most numerous and, if the car left the road even for a few yards, they collected on the radiator by the hundreds.

Not among the larger animals in the more open areas but in widely scattered thickets of small trees and bush, these plains are also thickly populated by a very desirable avian fauna. I learned to distinguish among the very numerous constituents of this a number of species including a very tasty francolin and two species of Guinea fowl, and on one occasion I found one species of the latter so abundant that a flock occupied the road for a hundred yards ahead of my car. By slightly increasing my rate of speed on that occasion I could have supplied succulent dinners to all the inhabitants of a fair sized town but, choosing instead to do some investigation, I discovered that African birds like African mammals will flee with alacrity the minute a man descends from his car.

In Nairobi, Kenya, where Mr. Krauss made his headquarters for more than two months, I spent little more than one week. With a population of some fifty thousand inhabitants of which about six thousand are Europeans, this is a fair sized town and a center of commercial importance to its own colony, to Tanganyika, and to Uganda. It is not in any sense a beautiful town, but as a large and typically African conglomeration of primitive and civilized features it is quite interesting. Its hotels, the number of which seems disproportionate to the size of the place until one recalls Nairobi's rank as a tourist center, are comparable to the good ones of Europe. The same can almost be said of the many well-stocked stores, and more perhaps, of the impressive vegetable market where, housed in a building modern in every detail, the fruits and vegetables of almost every clime can be obtained at standard prices.

Although rather poorly located in a treeless plain and regularly subjected earlier in its history to strong, dust-laden winds, Nairobi has to a great extent overcome that handicap by the wholesale planting of native and introduced trees. Because of their greater size, the usual Grevilleas, Ficus, Eucalyptus, and palms are the most conspicuous among these, but there are also many others including berry and fruit-bearing varieties so abundant as to make Nairobi one of the most favorable locations for our fruit fly work. One species of Strychnos, the Nux-vomica tree, was particularly well spread throughout the city and provided Mr. Krauss with a large part of his fly rearing material. The fruit of this tree is a small, yellow colored drupe and in many parks and public lots the ground was thickly carpeted with it.

The Coryndon Memorial Museum, a few blocks from the center of town, is well worth a visit. Founded by the Society of Natural History, and supported by it with only meager aid from the Colonial Government, this institution does honor to the enthusiasm and ability of its small and poorly rewarded staff.

Uganda

My travels in the Crown Colony of Uganda began with a short stay in the pleasant town of Kampala. Important as the largest commercial center of the colony, this town was to me chiefly interesting because of its population which consists predominantly of members of the Buganda tribe. Reputed to be the most advanced of the native peoples of Africa, this tribe constitutes a semi-rural community of idyllic charm; and nothing gave me more pleasure during the week that I spent in Kampala, or perhaps in all my African travels, than long evening walks which took me into the heart of their thickly populated districts. The happy laughter characteristic of the Negro rings there against a background of order, cleanliness, and comfort which is not remotely approached in any of the other African countries I visited. The people, protected in their tenancy by a wise government, own most of the land and live off it with relatively small effort. Most of them cultivate cotton, peanuts, or other readily marketable crops in addition to the cassava, millet and vegetables for their own staple consumption. They all own goats; a few own cattle; and, more perhaps as an index to social standing than because of comfort or necessity, practically every household boasts the possession of one or more bicycles. Their homes are invariably clean, near to the city often provided with electricity and running water, and in every instance surrounded by gardens the upkeep and appearance of which impress the visitor as objects of family rivalry. In the matter of clothing, individuals are still too often given to the fanciful combination of totally unrelated and sometimes ludicrously contrasting pieces of apparel, but on the whole everyone dresses becomingly in simple and light clothes of European pattern. The women, more distinctive than the men, dress in very bright colors and usually wear four or five skirts superimposed upon each other, with a fold of the material gathered in back into a sort of crinoline that in no way reduces the already respectable girth of the wearers.

There is still left to the Buganda a native king with a considerable measure of influence on the local affairs of the community. He is known by the title of "Kabaka" and he and his palace which crowns one of the numerous hillocks over which Kampala spreads are objects of almost pathetic reverence on the part of the natives.

After Kampala I spent a few days in Jinja where, in a country of similar physical features but entirely different population, my interest reverted to the flora and the wild life of the place.

Housed in a hotel removed little more than a stone's throw from Lake Victoria and the famous Rippon Falls, I made my first acquaintance with crocodiles and hippopotami and spent several pleasant evening hours observing the activities of the latter. Hidden from view during the warmer hours of the day in the deeper central portion of the lake, dozens of these animals make their appearance late in the afternoon near the shore. There, gamboling and cavorting in the water in a manner much like that of happy children in a swimming hole, they remain until dark, and later under the cover of night, they walk out on the land and often spend many hours wandering about. How far they wander I was not able to ascertain conclusively; but it was sworn to me that people had often met them in the streets of Jinja, and that it was a usual experience to find them roaming over a golf course

This man-powered ferry serves as a cheap and convenient way of crossing the Nile river in the West Nile District of the Northern Province, Uganda.

A rest camp in the West Nile District, Northern Province, Uganda.

which lies some 300 yards from the lake. Spending a good part of a clear night in this golf course, I myself did not meet any of the hippos therein, but I saw unmistakable traces of their recent presence and observed the deeply worn paths which they have traced in years of nightly visits. It was astounding that in one place these paths rose at angles of 60 or 70 per cent over a 200-foot cliff; and I considered myself cheated by chance in not being able to witness the hippopotami actually surmounting this obstacle. With their enormous weight and very short legs, it is surprising that they can climb at all, and it must be a memorable sight to see them scampering up grades of steepness that would tax even a man's ability.

Some of them came within twenty feet of me in the lake without seeming to take much notice of my presence, but I was told that under certain circumstances hippos will attack man, and that a light suddenly directed at them in the dark is one of the few things that will anger them. Sometime before, a visitor ignorant of this idosyncracy had been trampled to death in the yard of the hotel where I stayed. On learning this, needless to state, my own nocturnal explorations of Jinja were carried out without benefit of lights of any sort except the silvery radiance of helpful Luna.

The shores of Lake Victoria cannot be considered ideal home sites, among other reasons, because of the occasional appearance of enormous swarms of bothersome insects. While having my first dinner in the hotel I was witness and victim of one of these invasions which consisted of veritable clouds of very minute Chironomidae with a very distinct liking for tomato soup. Trying to trace their origin to the lake next morning, I failed to discover it, but found instead that some areas of the grass nearer the water and practically every bush or small tree were so thickly covered with the exuvia of another insect, an Ephemerid or May fly, that the leaves looked gray. On the under surface alone of one small leaf I counted 43 exuvia.

Near to Jinja, some 15 miles along the road to Kampala, I visited the only large plantation of sugar cane that I saw in Africa. Commonly known as "Lugazi," its official name is "The Uganda Sugar Company." It is owned by an East Indian financier. The majority of the employees are also East Indians, but of course there was also a Scotchman, and he, the Chief Engineer, filled me with tea and buns and between drinks showed me around his domain. The mill, of German make with 2 crushers and 12 rollers, has a daily capacity of 700 tons of cane and produces 14,000 tons of plantation white sugar per annum, most of which is consumed in Uganda itself. The total area of the plantation, most of it under cane, is around 7,000 acres; and the preferred cane variety is POJ 2878 with 2725 close behind. The cane appeared perfectly clean in so far as insect pests were concerned, and no one on the plantation was able to produce for my collection even a single specimen of the moth borer which is the only cane pest known in the region.

From Jinja, by a little known though important artery of commerce, the back road so to speak into the Belgian Congo, I journeyed eastward to Busingiro Forest. Employing a poor train from Jinja to Lake Kyoga, a paddle steamer across the lake, and an automobile from the lake to my final destination, the trip was neither rapid nor very comfortable, but I found full compensation for my troubles in the great beauty and interest of the route and its objective.

Situated between Lakes Kyoga and Albert, Busingiro Forest covers some 350 square miles and consists of several more or less adjacent but separate portions, of

The Uganda Sugar Company, fifteen miles from Jinja, Uganda.

Saw mill in Busingiro Forest, privately run under government control.

which one, Budongo Forest, is by far the largest and most interesting. On the very edge of this enormous mass of trees as the guest of W. J. Eggling, Assistant Conservator of forests, I lived in a house of size and comfort which I was far from expecting in that remote locality. Built on the slope of a steep hill, this residence commands a magnificent view quite reminiscent of our own Great Lakes District as we find it described in the tales of Fenimore Cooper. As one sat in the glow of late evening sipping the inevitable afternoon tea of every British household, with Lake Albert stretching all silvery on one hand, and on the other Budongo Forest an uninterrupted mass of trees fifteen miles long, it was not difficult to imagine that the last rays of the sun flickered and glimmered from the lances and tomahawks of Indians impatiently waiting behind trees for the darkness so propitious for their unpleasant habits. But of course there were no redmen in Budongo; nor were there likely to be any furtive black ones behind the trees, for this country is not heavily populated and the few negroes who go out after dark do so in noisy groups that stick to the widest and clearest openings they can find. Wild animals are still numerous enough even along the fringe of cultivation that borders the forest to make solitary night errands unsafe, particularly to natives too poor to travel in motor cars and by law prevented from possessing fire arms. A leopard had been killed not long before my stay on the very porch from which for three weeks I watched the sun set, and lions were of common occurrence on the road that ran a quarter of a mile below.

There are no pygmy people nor pygmy elephants in Budongo Forest such as are found in Ituri and other forests of West Africa, nor are the elephants of Budongo, strictly speaking, denizens of the forest. Their tracks can be found far into the forest, as I often did, but they indicate only the incursions of small detachments from large herds which make their permanent home in the basin of Lake Albert. Kindly invited by Mr. Eggling to take part in a hunt in this basin some 20 miles from Budongo, I observed the age-old paths which the elephants' migrations have worn on the face of the eastern escarpment. We failed actually to meet elephants on this occasion, however, and my first contact with them did not occur until a much later date in the West Nile District.

As might be surmised from its geographical location, the flora of Busingiro shows affinities both to the eastern and the western floras of Africa; and there are those who think it may represent a central remnant of a wide and continuous belt of forest once spanning the continent from coast to coast. If it ever existed, this belt has completely disappeared in most places due to climatic and physiographical changes; and the same fate is said to be evidently in store for Busingiro, which from an original tropical rain forest is slowly changing into a drier type with a consequent reduction of the species and individuals now found among its components. The Government of Uganda, I was glad to learn, is doing everything possible to retard this inevitable reduction, and if it ever reaches a stage of complete consummation it will be only in a small degree due directly to the activities of man which in this area are carefully regulated.

Among the innumerable species of plants which are found in the flora of Busingiro, of which even some of the common fringe-of-the-forest varieties are yet unknown to science, there are many timber trees of great value. Perhaps *Khaya*

Busingiro Forest Station, Uganda.

Communal granaries, West Nile District, Northern Province, Uganda.

anthotheca, the African mahogany, is the most important of these, but *Chlorophora excelsa* (Mvule), *Parinarium excelsum*, *Podocarpus gracilior*, and a very abundant species of Maesopsis also have a market demand. In one small mill which is privately run under the close supervision of the forestry authorities of Busingiro I saw fine logs of some of these trees destined, as I was informed, for the hammers and nails of Jinja, Kampala, and points even farther east.

After Busingiro, still as a guest of Mr. Eggling, I crossed Lake Albert and sailed down the Blue Nile in a comfortable little steamer to a spot on the map of the West Nile District called Pakwach. Thence, traveling in the front seat of Mr. Eggling's light delivery truck between Mr. Eggling and his cook, and most of the time holding his terrier on my lap, I traversed the whole length of the West Nile District to another spot called Soroti, where I regretfully left my genial companions and boarded the prosaic wood-burning train which overnight returned me to Nairobi.

Of course adventures continued to pile up in my diary during this latter part of my trip, but as they included for the most part experiences of personal interest only, such as a bout of malaria, a close escape from a white rhinoceros, and a pugilistic encounter with a tipsy station guard, I shall not record them here.

Soil and Plant Material Analyses by Rapid Chemical Methods—II

By Francis E. Hance

CONTENTS

Foreword

It was stated in the previous article "Rapid Chemical Methods" (R.C.M.) (2), prepared for publication in the summer of 1936, that research was in progress at that time, the purpose of which was to develop entirely new chemically stable, fast-to-light, inorganic color standards for use in colorimetric R.C.M. analyses. This work, which was undertaken by Q. H. Yuen, E. K. Hamamura, T. Nishimura, F. Fong and the author, is now complete. Discussion and details, with formulae, appear later in this publication.

As Hawaiian plantation agriculturists and Experiment Station workers extended their fields of study of soil, plant material, irrigation water, and factory by-products, it became necessary, from time to time, to augment existing R.C.M. procedures with supplementary assemblies having similar, yet equally efficacious, rapid analytical characteristics. Full details of all the newer R.C.M. analyses appear later in these pages.

Another subject to be discussed pertains to the marked advancements which have been made in remodeling and equipping plantation laboratories.

(Note: The greater portion of discussion and data appearing under "Color Standards" refers to a previously published manuscript describing various R.C.M. procedures.)

Color Standards

Equipment:

A number of excellent soil-testing kits are available today which are equipped with ingenious and practical devices for comparing colors of unknown solutions with standard color discs or plates. These are arranged together progressively by hue or shade in the longitudinal plane of the adjacently placed vial of test solution. The materials comprising the standard colors are, in most cases, durable and non-fading. Usually the entire color comparison assembly occupies but little space. Frequently it is a product of careful design and manufacturing skill. Nevertheless, these comparators are, in our opinion, not entirely satisfactory for R.C.M. laboratory usage, although they are unquestionably adequate for conventional "field" or "kit" analytical estimations.

The color comparison devices used in R.C.M. work are not portable. On the contrary, their position in the laboratory is a fixed one and a screen or hood is usually provided which gives the operator protection from all sources of extraneous light. R.C.M. "illuminators," as we term them, are equipped with calibrated electric light bulbs and snap switches for control of illumination. Examinations of test solutions by comparison with standard color solutions are made in a sliding rack, the latter moving back and forth on apparatus (painted dull [flat] black) before a source of illumination which is mellowed by an opal glass window diffusing softened light. The color standards are liquid solutions sealed into vials identical with those used in the tests. These standards are placed along the rack in colorimetric sequence. Notched recesses are provided between the standard vials for inserting the test solution vial in making a color reading. Other details concerning the "illuminators" may be found in the previous article on R.C.M. A full vial-length comparison between the color developed in the test solution and the two nearest "matches" of colored standards may be made before the illuminated field. This feature simplifies the matching performance and, we have found, adds to the precision of the determination.

The Color Standard Solutions:

We have found that, unfortunately, supposedly non-fading aniline dyes deteriorate quite rapidly when dissolved in ordinary solvents and when subjected alternately to the unavoidable warming and cooling in glass containers used as "standard" vials for R.C.M. colorimetric analyses.

The fugitive nature of such standards, the resulting uncertainty of their dependability *as* standards and the expense and labor involved in replacing them at frequent intervals led to an intensive experimental study in the development of colored solutions having greater durability and permanence. Colors of solutions of individual inorganic salts are, in many cases, both fast to light and permanently stable chemically under certain environmental conditions. However, the character of solvents, the changing temperatures to which the standards are subjected and the effects produced by chemical reactions when mixtures of two or more of these basic or primary colored solutions are brought together are factors which limit the possibilities of a development of this character. Phosphate blues, for instance, which are required in a large number of gradations in shade and hue, cannot successfully be produced from aqueous or ammoniacal solutions of copper salts in any of the many combinations which were studied. Similarly, aqueous solutions of cobalt salts, which are pink in color, were equally out of the picture. But combinations of strongly acid (7 parts hydrochloric acid to 3 parts distilled water) solutions of cobalt and copper chlorides produced a range of color effects in blue which completely covered the entire field of requirements for all classes of phosphate determinations at laboratory temperatures between 71° F. and 100° F. (25° C. and 41° C.). (This range of temperatures approximately embraces both extremes of cold and warmth which may prevail in laboratory buildings in the Territory of Hawaii, U.S.A.) Modifications of the formulae presented below may be made to meet different temperature ranges in other localities.

Preparation of Inorganic Color Standards for Phosphate Determination by R.C.M.:

In soils having comparatively low concentrations of phosphate it frequently happens that, during the digestion of the soil with the solvent, colored extractive matter is carried into solution. This colored impurity may not be entirely eliminated in the process of analysis. In a majority of cases, however, this *undesirable* feature is not encountered. Therefore, we usually obtain a colorless soil extract, or less commonly, one having a yellowish tinge. In the latter case the development of the phosphate blue must be made in this pale yellow medium and since the intensity of the developed blue is low (in low-phosphate soils) the resultant color in the test solution is of a distinctive greenish-blue hue. To meet this contingency a separate set of appropriately shaded color standards has been produced.

In the former case, where colorless soil extracts are obtained, normal phosphomolybdate blue colors are developed in the course of the analysis. A set of standards is provided for these normal determinations.

Furthermore, analyses of generally low-phosphate soils occasionally show such low concentrations of "available" (readily soluble) nutrient that very little coloration, or practically none, is produced in the final test solution. In such cases the result is reported as "low," comparison having been made with the color standard adjusted to match the natural color of the soil extract. In the R.C.M. scheme of

phosphate-standard classification, the letter "X" is used to denote the series of standards which have been prepared for use in the analysis of colorless soil extracts and the letter "Y" to denote the series of standards for use with extracts having a yellowish tinge.

To Prepare the R.C.M. Color Standards:

Solution A: 15 gm. cobaltous chloride ($CoCl_2.6H_2O$) per 100 ml. 7/10 HCl.
Solution B: 5 gm. cupric chloride ($CuCl_2.2H_2O$) per 100 ml. 7/10 HCl.
Solution C: 1 ml. Solution "B" diluted to 25 ml. with 7/10 HCl.
7/10 HCl: 7 volumes of concentrated HCl (12 normal) diluted with 3 volumes of distilled water.
$CoCl_2.6H_2O$: Baker's C.P.
$CuCl_2.2H_2O$: Merck's Reagent Grade.
Conc. HCl: Any C.P. grade.
Solution I: 5 gm. potassium dichromate ($K_2Cr_2O_7$) per 500 ml. distilled water. Filter before making up to the mark.
Solution II: 50 gm. cobaltous sulfate ($CoSO_4.7H_2O$) per 500 ml. distilled water. Filter before making up to the mark.

$K_2Cr_2O_7$: C.P.
$CoSO_4.7H_2O$: C.P.

Soil and Cane Juice Phosphate Color Standards:

Series X, Soil Phosphate

(For use in matching colors developed in water-white soil extracts.)

	ml. solution required				
Standard	Sol'n A	7/10 HCl	Sol'n C	Distilled water	Approximate total volume
Low	...	100.0	...	...	±100 ml.
Doubtful	9.5	65.0	1.8	23.7	±100 ml.
Medium	13.6	61.2	3.4	21.8	±100 ml.
High	15.9	61.0	6.1	17.0	±100 ml.

Deliver each solution, the HCl and the distilled water from individual calibrated burettes to a common container. The relative amounts of 7/10 HCl and water are very critical as far as the proper shade of color is concerned.

Series Y, Soil Phosphate

(For use in matching colors developed in soil extracts having a yellowish tinge.)

	ml. solution required						
Standard	Sol'n I	Sol'n II	Sol'n A	7/10 HCl	Sol'n C	Distilled water	Approximate total volume
Low	2.5	5.0	...	...	...	242.5	±250 ml.
Doubtful	...	...	9.2	63.2	4.6	23.0	±100 ml.
Medium	...	...	13.2	59.2	7.9	19.7	±100 ml.
High	...	...	15.5	59.5	9.5	15.5	±100 ml.

Proceed as directed under Series X, soil phosphate color standards, observing the same precautions regarding the relative amounts of 7/10 HCl and water.

High-Register, Soil Phosphate

(For use in matching colors developed in soil extracts, the latter containing amounts of readily soluble phosphates in excess of the highest concentrations encountered in the X and Y Series.)

Standard	ml. solution required: Sol'n A	7/10 HCl	Sol'n C	Distilled water	Approximate total volume
H.R. I	16.0	62.0	11.0	11.0	±100 ml.
H.R. II	21.9	54.6	13.7	9.8	±100 ml.
H.R. III	27.5	45.9	17.4	9.2	±100 ml.
H.R. IV	32.8	38.6	20.1	8.5	±100 ml.
H.R. V	40.1	28.7	24.1	7.1	±100 ml.
H.R. VI	44.5	22.2	26.6	6.7	±100 ml.
H.R. VII	50.8	15.4	27.7	6.1	±100 ml.

Proceed as directed under Series X, soil phosphate color standards, observing the same precautions regarding the relative amounts of 7/10 HCl and water.

Soil Phosphate Fixation

Standard	ml. solution required: Sol'n A	7/10 HCl	Sol'n C	Distilled water	Approximate total volume
0	44.9	32.8	22.3	...	±100 ml.
10	37.2	41.3	21.5	...	±100 ml.
20	29.9	48.3	19.4	2.4	±100 ml.
30	24.5	56.5	16.0	3.0	±100 ml.
40	18.5	62.5	12.0	7.0	±100 ml.
50	13.0	66.5	7.5	13.0	±100 ml.
60	9.7	69.4	4.2	16.7	±100 ml.
70	6.6	69.0	2.5	21.9	±100 ml.
80	4.3	70.9	0.7	24.1	±100 ml.
90	1.8	73.3	...	24.9	±100 ml.

Proceed as directed under Series X, soil phosphate color standards, observing the same precautions regarding the relative amounts of 7/10 HCl and water.

Phosphate in Juice

(Applicable to analyses of plant saps, root pressure liquids, crusher juice, etc.)

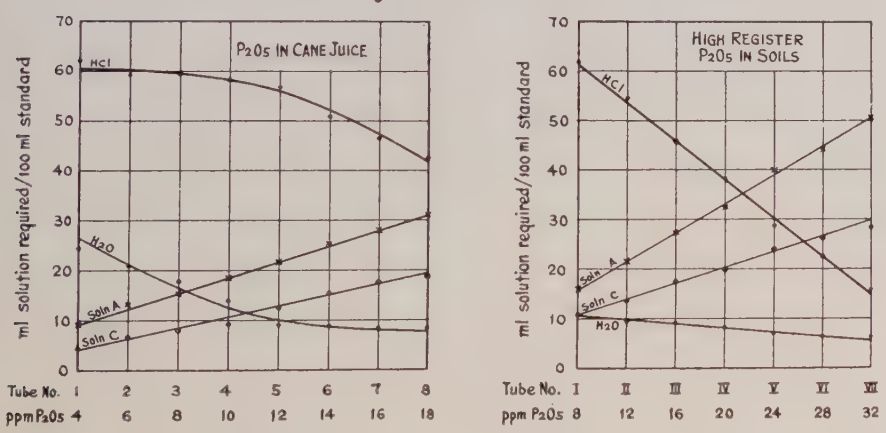
Standard	ml. solution required: Sol'n A	7/10 HCl	Sol'n C	Distilled water	Approximate total volume
C.J. 1	9.0	62.0	4.5	24.5	±100 ml.
C.J. 2	13.2	59.2	6.6	21.0	±100 ml.
C.J. 3	15.5	59.5	7.1	17.9	±100 ml.
C.J. 4	18.6	58.1	9.3	14.0	±100 ml.
C.J. 5	21.6	56.8	12.5	9.1	±100 ml.
C.J. 6	25.2	50.5	15.2	9.1	±100 ml.
C.J. 7	27.8	46.3	17.6	8.3	±100 ml.
C.J. 8	31.3	42.4	17.8	8.5	±100 ml.

Proceed as directed under Series X, soil phosphate color standards, observing the same precautions regarding the relative amounts of 7/10 HCl and water.

Checking Preparation of Color Standards: Graphical methods of analysis were employed in checking the proportions of component Solutions A, C, HCl, and water in the color standards of each series. For instance, in the preparation of each phosphate standard, Mr. Yuen experimented with various combinations of the 4 inorganic components until a blend was produced which matched the developed color in a phosphate solution of definite concentration. The color comparison was made visually under the same conditions as obtained in the regular rapid chemical procedure. Upon completion of a whole set of standards in this manner, the entire set was again checked colorimetrically against solutions of known phosphate concentration. Since the concentrations of phosphate represented in each of the solutions were graded to increase in a regular order, it was reasoned that were the components of each color standard plotted graphically the resulting graphs should constitute a pattern which would indicate a definite order of systematic increase or decrease for each component throughout the series. Thus, by graphical means, an additional check was provided to test the progressive regularity of increase or decrease in the components blended together from step to step in any given series of standards.

In the preparation of these graphs the tube numbers of the standards were plotted on the X-axes and the amount of each basic solution required to produce 100 ml. of the corresponding color standards was placed on the appropriate Y-axes. The plotted points then form the basis for drawing curves or line graphs for each component used. Results of these graphical analyses indicate that the prepared phosphate color standards vary systematically and apparently in a logical manner. Graphs for the high-register soil phosphate and cane juice phosphate standards are illustrated below as examples.

Graphs showing the ml. of component solutions required to produce 100 ml. of each inorganic P_2O_5 color standard in a series



Rechecking Color Standards Against Solutions of Known Phosphate Concentration:

Soil and Cane Juice Standards: Aliquots of a standard solution of phosphate (0.1 mg. P_2O_5 per ml.) dissolved in water are made up to 100 ml. in volume with Reagent 4, P_2O_5 (see Soil and Plant Material Analyses by Rapid Chemical Methods [2]). The characteristic phospho-molybdic blue color is developed in the various diluted solutions by the introduction of stannous chloride reagent as in the regular soil or cane juice procedure of analysis. In making these checking tests it is essential to bear in mind and to make allowances for:

(*a*) The somewhat darker hues in the "X" standards as contrasted with the "Y" series.

(*b*) The slightly greenish-blue coloration in the "Y" standards (as a result of the pale yellowish tinge in the soil extracts).

(*c*) The greater depth of and increased intensity of blue color in the high-register standards.

(*d*) The concentration of P_2O_5 in the test solutions for checking soil color standards. The P_2O_5 solutions used in checking color standards contain concentrations of phosphate which are less than their equivalent concentrations calculated from the percentages expressed on the respective tubes. Under the conditions of R.C.M. analysis, the color developed in the soil extract is less intense than that produced in a standard phosphate acid-molybdate solution containing an equal amount of phosphate. A series of soil extracts was made and each was divided into 2 parts. One part was analyzed for P_2O_5 by R.C.M. and the other part by a more elaborate laboratory method. The results indicated that in order to bring about an agreement between the R.C.M. and the laboratory procedures, the latter being taken as a standard method of analysis, it was found in the course of protracted study with many soil extracts that it was necessary to decrease the concentration of P_2O_5 in the checking solution to make it equivalent to a soil extract containing an amount of P_2O_5 as indicated by the R.C.M. color standards. Hence, by adjustment, the incomplete development of color in the soil extract is more accurately evaluated in the percentages assigned to the standard tubes.

There are several factors which influence the development of the phosphomolybdic blue in the soil extract. Among these may be mentioned the presence of a large amount of ferric iron; titanium also may markedly depress the blue color formation. In addition, any incomplete removal of organic matter from the soil extract will exert a similar effect. Any or all of these factors may adversely influence a normal reading.

The foregoing explanations are presented in order to make clear the apparent anomalies which may be observed in the soil phosphate data appearing below on checking procedure.

Checking Procedure, Phosphates: The color of each standard is adjusted to match the blue color developed by stannous chloride reagent in the solution of chemically pure salt of phosphate in Reagent 4, P_2O_5. The corresponding percentage of P_2O_5, as it will appear in the analytical procedure, is shown in another column.

Standard Soil Phosphate	Per cent P_2O_5 indicated in analytical procedure	ml. standard P_2O_5 sol'n (0.1 mg. P_2O_5/1.0 ml. water) to be used in making up the test solution to 100 ml. with Reagent 4, P_2O_5
X & Y Low	Less than 0.0008	0
X & Y Doubtful	Between 0.0008 and 0.0015	4.0
X & Y Medium	Between 0.0015 and 0.004	6.0
X & Y High	Greater than 0.004	8.0
H.R. I	0.004	8.0
H.R. II	0.006	12.0
H.R. III	0.008	16.0
H.R. IV	0.010	20.0
H.R. V	0.012	24.0
H.R. VI	0.014	28.0
H.R. VII	0.016	32.0

Checking the Cane Juice Color Standards: The cane juice color standards are calibrated without the necessity of recourse to any adjustments which may be needed to compensate for chemical reactions or absorptions interfering with the normal development of the molybdic blue.

Standard Cane Juice	Per cent P_2O_5 indicated in analytical procedure	ml. standard P_2O_5 solution (0.1 mg. P_2O_5/1.0 ml. water) to be used in making up the test solution to 100 ml.
C.J. 1	.004	4
C.J. 2	.006	6
C.J. 3	.008	8
C.J. 4	.010	10
C.J. 5	.012	12
C.J. 6	.014	14
C.J. 7	.016	16
C.J. 8	.018	18

Checking the Soil Phosphate Fixation Color Standards: Solutions of phosphate, having known concentrations of P_2O_5, are prepared from a C. P. phosphate salt, as indicated in the table which follows. An aliquot is taken from each, as in the regular fixation determination, and transferred to a shell vial. One ml. of ammonium molybdate reagent is then added to each vial and the color is developed by the addition of stannous chloride reagent.

Column 1	Column 2	Column 3	Column 4
Fixation Index Soil Phosphate	ml. known P_2O_5 sol'n (see text above)	Dilute sol'n of Column 2 with H_2O to total volume of:	p.p.m. P_2O_5 in diluted test sol'n (Column 3)
0	Orig. 100 p.p.m. P_2O_5	—	100.0
10	13.50 ml. of solution containing 100 p.p.m. P_2O_5	20 ml.	67.5
20	8.0 ml. of solution containing 100 p.p.m. P_2O_5	20 ml.	40.0
30	5.0 ml. of solution containing 100 p.p.m. P_2O_5	20 ml.	25.0
40	3.0 ml. of solution containing 100 p.p.m. P_2O_5	20 ml.	15.0
50	2.0 ml. of solution containing 100 p.p.m. P_2O_5	20 ml.	10.0
60	11.0 ml. of solution containing 10 p.p.m. P_2O_5	20 ml.	5.5
70	6.0 ml. of solution containing 10 p.p.m. P_2O_5	20 ml.	3.0
80	3.50 ml. of solution containing 10 p.p.m. P_2O_5	20 ml.	1.75
90	2.00 ml. of solution containing 10 p.p.m. P_2O_5	20 ml.	1.00

The Use and Care of Inorganic Phosphate Color Standards:

It has been stated previously that these standards have been calibrated to give accurate readings between the limits of 71° and 100° F. (actually 71.6° and 100.4° F.).

Anyone familiar with the chemical and physical properties of cobalt salts will understand the reasons which make such a calibration necessary. With the solutions as they have been prepared and at temperatures other than those between the stated limits, changes in hue and intensity of the various colors will occur, but the change is

a temporary one. Restoring the surroundings of the standards to temperatures within the stated limits will automatically restore the original colors.

It is not a difficult matter to calibrate the standards between limits of temperatures which may prevail indoors at localities other than Hawaii. In many cases the Hawaiian lower limit (71° F.) is not far removed from comfortable laboratory temperatures, regardless of the location. At temperatures close to the upper Hawaiian limit (100° F.), very few analysts anywhere could carry on with any degree of consistency. Therefore, it is believed that the formulae which have been presented will require little or no modification for the general worker in this field.

It is a common experience, however, even in sub-tropical Hawaii, to find the standards off-color somewhat after exposure on chilly nights in open laboratories. It may appear as questionable, but it is true, nevertheless, that changes in the color of the standards due to increases of temperature above the 100° F. limit have not been noted in Hawaii, provided direct exposure to sunlight has not taken place. Although it is seldom necessary to do so, the correction for restoring the standards to their normal conditions due to changes induced by exposure to abnormal temperatures is, of course, quite obvious. It is of advantage, however, to use a definite technic. The following procedure (in 4 steps) has been found quite simple and effective:

(a) Place the tubes containing the standards in a 250-ml. beaker. Add water to the level of the solution in the tubes.

(b) Remove tubes from beaker.

(c) To warm: Heat the measured water in the beaker to a temperature of about 82° F. Remove from source of heat, immerse tubes for 3 minutes, remove and wipe off excess water.

(d) To cool: Mark the level of water in the beaker, add a small amount of ice and stir until the temperature reaches about 75° F. Remove the ice and restore the original level of water in the beaker, if necessary. Immerse color standards for a few minutes, remove and wipe off excess moisture.

Precautions: The most effective and advantageous packaging of the colored standards would entail sealing the liquid contents in all-glass containers. The selection of tubes to carry these standards, tubes which are identical to those used in the analyses, preclude this desirable practice. Because of mechanical difficulties, such a glass seal, if made, will usually become shattered, due to improper handling and, if not to this cause, certainly to the difficulties of annealing. As a consequence, rubber stoppers are used, but beforehand they are subjected to thorough and successive "cleaning" in boiling dilute alkali, dilute acid, and distilled water.

During normal use, and on standing, occasionally a few solid particles may be observed on the inner surface of the rubber stoppers, or the particles may settle to the bottom of the enclosed colored solutions. Experience so far gained indicates that this condition may be disregarded. The colors of the standards have not been found to undergo any measurable alteration in this, apparently, minor occurrence. While on the subject of rubber stoppers, it may be stated that, after the colored solution is placed in its tube and the rubber stopper has been inserted, the protruding portion of the stopper is cut off flush with the tube and the end is then sealed by dipping it into melted paraffin or colorless lacquer. Later, the sealed end of the tube is color-coded by small dots or stripes to distinguish it properly as a unit of the series to which it belongs. Small letters or numerals (or both) are placed at or near the top of the tube to designate its grade or value in its series.

New Inorganic Color Standards For Use in the Determination of Ammoniacal Nitrogen by R. C. M. (see previous article [2]):

Solution I: 5 gm. potassium dichromate ($K_2Cr_2O_7$) C. P. per 500 ml. distilled water. Dissolve the salt in a 250-ml. beaker. Filter into a volumetric flask, washing filter paper thoroughly with distilled water. Make up to mark and mix thoroughly.

Solution II: 50 gm. cobaltous sulfate ($CoSO_4.7H_2O$) C. P. per 500 ml. of solution, using distilled water. Filter before making up to the mark.

Ammoniacal Nitrogen Stds.	ml. solution required		Make up to volume indicated below with distilled water
	Sol'n I	Sol'n II	
1	1.25	1.75	250 ml.
2	2.9	3.8	250 ml.
3	4.5	6.5	250 ml.
4	6.35	9.8	250 ml.
5	8.1	14.5	250 ml.
6	11.1	21.3	250 ml.
7	14.3	31.0	250 ml.
8	22.0	52.0	250 ml.

Deliver each solution from individual calibrated burettes to a common container, observing the precautions indicated for the preparation of the phosphate color standards.

New Inorganic Color Standards For Use in the R.C.M. Determination of Magnesia (MgO) in Irrigation or Other Waters:

The method of analysis is described elsewhere in this paper.

Solution I: 250 gm. cobaltous sulfate ($CoSO_4.7H_2O$) per 500 ml. of final solution, using distilled water. Weigh the salt, dissolve it in about 300 ml. distilled water, heat to effect solution, cool to room temperature, filter into 500-ml. volumetric flask, wash filter and make up to mark.

Solution II: 5 gm. potassium dichromate ($K_2Cr_2O_7$) per 500 ml. of final solution, using distilled water. Dissolve salt in the cold with about 300 ml. distilled water. Filter into 500-ml. volumetric flask, wash filter and make up to mark.

Solution III: Concentrated sulfuric acid (36 N) C. P. placed in 30-ml. T. K. dropping bottle.

Magnesia in Irrig. Water Standard	ml. solution required			Distilled water sufficient to make volume of
	Sol'n I	Sol'n II	Sol'n III	
1	20.00	12.50	25 drops*	250 ml.
2	24.25	11.50	25 drops	250 ml.
3	28.50	10.50	25 drops	250 ml.
4	33.00	9.25	25 drops	250 ml.
5	37.25	8.25	25 drops	250 ml.
6	41.50	7.25	25 drops	250 ml.
7	45.75	6.00	25 drops	250 ml.
8	50.00	5.00	25 drops	250 ml.

*Exact amount required not critical.

Deliver solutions to clean volumetric flasks from burettes. Make up to mark with distilled water at temperature for which flask is calibrated.

Color Standards For Use in the R.C.M. Determination of Magnesium in Soil:

The method of analysis is described elsewhere in this contribution.

This procedure has been recently developed. For the present, color standards have been prepared for this determination from aniline dyes. Later, the more permanent inorganic colored solutions will be substituted, if that is found possible.

Solution I: 0.5 gm. Brilliant Wool Blue G. Extra dissolved in 95 per cent ethyl alcohol and made to a volume of one liter with the same solvent.

Solution II: 0.1 gm. Eryothrosine Red dissolved in 95 per cent ethyl alcohol and made to a volume of 500 ml. with the same solvent.

Solution III: 0.25 gm. Metanil Yellow brought into solution and made to a volume of one liter with 95 per cent ethyl alcohol.

Magnesium in Soil Standard	ml. solution required			95% ethyl alcohol sufficient to make volume of
	Sol'n I	Sol'n II	Sol'n III	
1	3.625	12.125	1.875	250 ml.
2	3.625	11.25	1.875	250 ml.
3	3.625	10.00	1.875	250 ml.
4	4.00	7.50	1.875	250 ml.
5	4.75	7.50	1.875	250 ml.
6	5.25	5.50	1.875	250 ml.
7	5.25	3.75	1.875	250 ml.
8	5.50	3.00	1.875	250 ml.

Deliver solutions to clean volumetric flask from burettes. Make up to the mark with 95 per cent ethyl alcohol at temperature for which flask is calibrated.

Phosphate Color Standards From Aniline Dyes:

Independently of the development of inorganic phosphate color standards, improvements were made in the permanence and durability of equivalent standards prepared from organic dye solutions. These color standards have remained satisfactory in regular laboratory service for periods averaging about 6 months. They were prepared as follows:

Solution 2A: Dissolve 1 gm. of National Brilliant Wool Blue G. Extra in 400 ml. of 95 per cent ethyl alcohol and make up volume to 1000 ml. with distilled water.

Solution A: Dissolve 0.5 gm. of National Brilliant Wool Blue G. Extra in 400 ml. of 95 per cent ethyl alcohol and make up volume to 1000 ml. with distilled water.

Solution B: Dissolve 0.25 gm. of National Metanil Yellow, Schultz No. 134, in 400 ml. of 95 per cent ethyl alcohol and make up volume to 1000 ml. with distilled water.

Solution C: Dissolve 0.5 gm. of National Erythrosine, Schultz No. 592, in 200 ml. of 95 per cent ethyl alcohol and make up volume to 500 ml. with distilled water.

Solution D: Dissolve 0.5 gm. of National Brilliant Milling Green B, Schultz No. 503, in 400 ml. of 95 per cent ethyl alcohol and make up volume to 1000 ml. with distilled water.

Deliver the following portions into 250-ml. flasks. Make up to volume with distilled water and mix well.

Soil Phosphate Standards	ml. solution required						Total Volume
	95% ethyl alcohol	Sol'n 2A	Sol'n A	Sol'n B	Sol'n C	Sol'n D	
X—High	100	0	26	8.0	5.2	0	250 ml.
X—Medium	100	0	17	4.5	3.0	0	250 ml.
X—Doubtful	100	0	11	3.5	2.0	0	250 ml.
X—Low	0	0	0	0	0	0	250 ml.
Y—High	100	0	30	10.0	5.0	0	250 ml.
Y—Medium	100	0	20	7.0	4.0	0	250 ml.
Y—Doubtful	100	0	11	4.0	1.5	0	250 ml.
Y—Low	50	0	0	2.5	0	0	250 ml.
H.R. I	100	0	26	8	5.2	0	250 ml.
H.R. II	100	22.5	0	10.8	6.0	0	250 ml.
H.R. III	100	36.0	0	15.0	8.0	0	250 ml.
H.R. IV	70	52.0	0	15.0	7.0	23	250 ml.
H.R. V	60	50.0	0	18.0	15.0	30	250 ml.
H.R. VI	60	50.0	0	20.0	21.0	30	250 ml.
H.R. VII	30	50.0	0	21.0	18.0	41	250 ml.

Cane Juice Standards	ml. solution required						Total Volume
	95% ethyl alcohol	Sol'n 2A	Sol'n A	Sol'n B	Sol'n C	Sol'n D	
1	100	0	13	6	3.3	0	250 ml.
2	100	0	18	6	4.0	0	250 ml.
3	100	0	26	8	5.2	0	250 ml.
4	100	0	32	8.5	5.0	0	250 ml.
5	100	22.5	0	10.8	6.0	0	250 ml.
6	100	29.0	0	13.0	7.0	0	250 ml.
7	100	36.0	0	15.0	8.0	0	250 ml.
8	100	42.0	0	15.0	8.0	0	250 ml.

The R.C.M. Determination of Total Nitrogen in Plant Material

This method is intended to supplement the more elaborate procedure described in the previous paper (2). In the latter method, the above-ground portion of the plant was collected, dried and then ground to a granular powder in a power mill. Several objections were found to the procedure. In the first place, the freshly collected material was bulky and required unusual care and space in the process of air-drying to protect it from dust, dirt, and fermentation. Secondly, it was difficult to disintegrate properly preparatory to grinding. Thirdly, a field nitrogen study, carried on during a crop cycle, entailed the removal from the field of no inconsiderable amount of cane. The removal of sampled material not only broke the continuity of the cane row, but allowed greater access of air and light to the remaining crop which later was to be used in the course of the study.

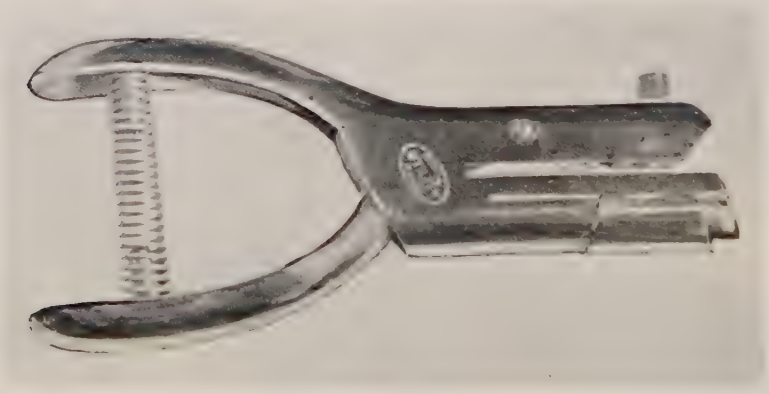
In spite of these objections, the procedure does have certain outstanding merits and is being used at the present time in a number of plantation research projects.

The modification which is described here eliminates entirely the removal of any appreciable amount of the crop and also the necessity of preparation and drying of samples for analysis.

In the life of a growing cane crop, from its earliest stages to its maturity, the major chemical activity in the plant takes place within the leaf tissue. It was believed, therefore, that absorption of plant nutrients from the soil by the crop should

be reflected from time to time by changes in the relative or total amounts of absorbed nutrients and moisture found in the leaf tissue of the plant. The work of A. Ayres, Assistant Chemist, and other investigators at this Experiment Station has shown marked differences in the nitrogen composition of the younger and older green leaves of the cane plant. In his study on sampling technic for the method under discussion, L. E. Davis, Associate Chemist, proposed, in due course, that, counting from the top of the plant, the third to the seventh leaves constituted a region from which samples may be secured for analysis which may quite satisfactorily represent the nutrient constituents present in the crop at given stages in its development.

Some years ago, the late Y. Kutsunai, Associate Agriculturist of this Experiment Station, developed a method of leaf sampling by cutting small discs in the growing leaves, using an ordinary ticket punch. This "ticket punch" system of sampling was adopted by Mr. Davis for the present procedure. The advantages over the older technic are many. A cane leaf appears to withstand a number of punch-hole removals of tissue without doing it any noticeable injury. Therefore, in a study of a growing crop, the investigator may return to the same plant, or more directly, to the same leaf, in sampling at progressive intervals of its growth. No damage is done to the crop thereby and no breaks are made in the continuity of the crop line. Fifty or more discs may constitute a sample adequate for analysis. The ticket punch which is used carries a tightly fitting receptacle which automatically collects the punched specimens. The collected green-leaf discs may be placed in a small air-tight, metal, tared container, weighed on a balance and then introduced directly to the Kjeldahl flask for digestion. No drying, grinding or other preparation for analysis is required. A photograph of the punch used in this work appears herein. It may be purchased for $3.00.



Ticket punch for sampling cane leaves.

Equipment Required

Nitrogen-in-cane-juice assembly, with the exception of:
1 pipette (bacteriological), 1 ml.
2 juice screens.
2 beakers, Pyrex glass, 600 ml.
2 beakers, Pyrex glass, 400 ml.
1 pipette, volumetric, 25 ml.
¼ lb. cane juice preservative.

In addition there will be needed:
1 balance, analytical, sensitive to 2 mg.
1 punch, with receptacle, $^3/_{16}$"-¼" die.
12 beakers, Pyrex glass, 50 ml.
2 doz. tin boxes, ¼ oz., with tight-fitting covers.

Procedure

1. Obtain samples in the field from growing cane.

2. Confine attention to stalks bearing at least 6 leaves.

3. Sample the third, fourth and fifth leaves on each stalk selected (counting the spindle, or first incompletely unfurled leaf, as the first leaf). Punch one disc from each leaf at a point about midway from tip to base and about midway from margin to midrib.

4. Sample 15 to 25 stalks representing 45 to 75 discs, or between 0.2 and 0.4 gram of green tissue.

5. Transfer discs to a small tin box and cover tightly.

6. Weigh the box with cover and contents. Transfer the discs to a Kjeldahl flask, 300-ml. capacity. Weigh the cover and box again. The difference in weight represents the green weight of the sample. Record the weights.

7. Proceed with Steps 1-b to 8 of the procedure for the rapid estimation of nitrogen in cane juices.

8. Pipette 5 ml. of the distillate into a clean, dry 50-ml. beaker. Add 25 ml. of Reagent 18, total N, and mix.

9. Pipette 5 ml. of the diluted solution into each of 2 comparison vials. Add one ml. of Reagent 6, N to each with the special pipette. Stopper and let stand one minute.

10. Compare on the illuminator with the ammonia nitrogen in soil color standards.

11. Refer to the table below of Percentage Nitrogen in Cane Leaves.

PER CENT TOTAL NITROGEN IN CANE LEAVES

(Green-weight basis)

5 ml. distillate—25 ml. Reagent 18, total N

Green weight	Reading, tube number						
Grams	2	3	4	5	6	7	8
.200	.18	.30	.42	.54	.72	.90	1.20
.205	.18	.29	.41	.53	.70	.88	1.17
.210	.17	.29	.40	.51	.69	.86	1.14
.215	.17	.28	.39	.50	.67	.84	1.12
.220	.16	.27	.38	.49	.66	.82	1.09
.225	.16	.27	.37	.48	.64	.80	1.07
.230	.16	.26	.37	.47	.63	.78	1.04
.235	.15	.26	.36	.46	.61	.77	1.02
.240	.15	.25	.35	.45	.60	.75	1.00
.245	.15	.25	.34	.44	.59	.73	.98
.250	.14	.24	.34	.43	.58	.72	.96
.255	.14	.24	.33	.42	.56	.71	.94
.260	.14	.23	.32	.42	.55	.69	.92
.265	.14	.23	.32	.41	.54	.68	.90
.270	.13	.22	.31	.40	.53	.67	.89
.275	.13	.22	.31	.39	.52	.66	.87
.280	.13	.21	.30	.39	.51	.64	.86
.285	.13	.21	.29	.38	.51	.63	.84
.290	.12	.21	.29	.37	.50	.62	.83
.295	.12	.20	.28	.37	.49	.61	.81
.300	.12	.20	.28	.36	.48	.60	.80
.305	.12	.20	.28	.35	.47	.59	.79
.310	.12	.19	.27	.35	.47	.58	.78
.315	.11	.19	.27	.34	.46	.57	.76
.320	.11	.19	.26	.34	.45	.56	.75
.325	.11	.18	.26	.33	.44	.55	.74
.330	.11	.18	.25	.33	.44	.55	.73
.335	.11	.18	.25	.32	.43	.54	.72
.340	.11	.18	.25	.32	.42	.53	.71
.345	.10	.17	.24	.31	.42	.52	.70
.350	.10	.17	.24	.31	.41	.51	.69
.355	.10	.17	.24	.30	.41	.51	.68
.360	.10	.17	.23	.30	.40	.50	.67
.365	.10	.16	.23	.30	.39	.49	.66
.370	.10	.16	.23	.29	.39	.49	.65
.375	.10	.16	.22	.29	.38	.48	.64
.380	.09	.16	.22	.28	.38	.47	.63
.385	.09	.16	.22	.28	.37	.47	.62
.390	.09	.15	.22	.28	.37	.46	.61
.395	.09	.15	.21	.27	.36	.46	.61
.400	.09	.15	.21	.27	.36	.45	.60

The R.C.M. Determination of Potash and Phosphate in Cane Leaves*

In addition to the determination of nitrogen in cane leaves, R.C.M. procedures have been developed for estimations of potash and phosphate, using ticket punch samples.

Equipment Required

Potash-and-phosphate-in-cane-juice assemblies, with the exception of the following items, which are not required:

12 funnels, short stem, 90 mm. dia.
1 box Whatman No. 12, 18.5-cm. folded filter paper.
1 pipette, transfer, straight type, 1 ml.
2 pipettes, medicine dropper, calib. 1 ml.
¼ lb. cane juice preservative.
1 pipette, special, 5 ml.
2 pipettes, volumetric, Exax, 5 ml.

In addition, there will be needed:

1 balance, analytical, sensitive to 2 mg.
1 punch, with receptacle, 3/16″-¼″ die.
36 beakers, Pyrex glass, 100 ml.
2 doz. tin boxes, ¼ oz., with tight-fitting covers.
½ lb. conc. nitric acid, special, in g.s.b.**
½ lb. conc. hydrochloric acid, special, in g.s.b.**
12 funnels, glass, 65 mm. dia.**
1 pkg. Munktell No. 3, 11-cm. filter paper.**
2 dropping bottles, with T. K. stoppers, 30 ml.**
1 electric hot plate.**
1 pipette, volumetric, 10 ml.**
1 pipette, volumetric, 25 ml.
2 pipettes, Mohr 1 ml., marked to deliver in 0.1 ml. portions.
1 gal. Reagent 8, N.
12 cover glasses, 2½″ dia.
12 stirring rods, 4-inch length.

Procedure

Preparation of Sample

1. Obtain samples in the field from growing cane.
2. Confine attention to stalks bearing at least 6 leaves.
3. Sample the third, fourth and fifth leaves on each stalk selected (counting the spindle, or first incompletely unfurled leaf, as the first leaf). Punch one disc from each leaf at a point about midway from tip to base and about midway from margin to midrib.
4. Sample 15 to 25 stalks, representing 45 to 75 discs, or between 0.2 and 0.4 gram of green tissue.

Note: It is not necessary to obtain more than one specimen for potash and phosphoric acid, or 2 where nitrogen estimations are also desired. However, it will not take long to obtain an additional sample, which will then be available in case of an accident or exceptionally low values for potash or phosphate.

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* Refer to directions for potash and phosphate in cane juice for analytical detail not repeated here (2).

** Note: Items included in soil potash or phosphate assemblies.

5. Transfer discs to a small tin box and cover tightly.

6. Weigh the box with cover and contents. Transfer the discs to a 100-ml. beaker. Weigh the cover and box again. The difference in weight represents the green weight of the sample. Record the weights.

7. Add to the beaker 10 drops conc. nitric acid and 30 drops conc. hydrochloric acid. Cover with a 2½" cover glass and place on an electric hot plate at low heat. After 5 minutes, remove the cover and allow the liquid to evaporate almost to dryness. Stir with a stirring rod towards the end to macerate the tissue and to avoid scorching.

8. Repeat Step 7 twice. Finally, allow the contents to become as nearly dry as possible without scorching. Cool.

9. Add 50 ml. Reagent 8, N from 250-ml. dispensing burette.

10. Stir thoroughly and filter through a dry 11-cm. filter paper into a 100-ml. beaker.

11. Transfer 25 ml. of the filtrate to a 100-ml. beaker and 10 ml. to a 50-ml. beaker. Evaporate to dryness. *Avoid scorching.*

12. Add 5 drops conc. nitric acid and again evaporate to dryness. Repeat 6—8 times.

13. Add 10 drops conc. hydrochloric acid and evaporate to dryness. Repeat twice. Cool.

Estimation of Potash

1. Add 5 ml. of Reagent 10, K_2O to the 100-ml. beaker previously containing 25 ml. of the filtrate from Step 11 above. Stir thoroughly.

2. Transfer 1 ml. to a potash vial with a pipette marked to deliver in 0.1-ml. portions and proceed according to the directions for potash in soil, Steps 7—13.

3. If a reading of 3 is obtained, repeat Step 2, using instead of 1 ml., 0.8, 0.6, 0.4, 0.3 or 0.2 ml. with 0.2, 0.4, 0.6, 0.7 or 0.8 ml. of Reagent 10, K_2O, respectively (to make a volume of 1.0 ml.), until a reading of 2 is obtained. Refer to the table and average the results.

4. If a reading of 4 is obtained with 1 ml. of the solution, employ different aliquots until readings of both 2 and 3 are obtained. Refer to the table and average the results.

5. If readings of 2 or 1 are obtained with 1 ml. of the solution, it will be necessary to prepare a fresh sample, according to Steps 1—10 (Preparation of Sample), and in Step 11 to transfer 45 ml. of the filtrate instead of 25 ml. Then proceed as above. Multiply values obtained from the table by the factor 0.56 to obtain the percentages of potash.

Estimation of Phosphate

1. Add 8.5 ml. of Reagent 4, P_2O_5 from a 50-ml. burette to the 50-ml. beaker previously containing 10 ml. of the filtrate from Step 11 (Preparation of Sample). Stir thoroughly.

2. Transfer entire contents to a phosphate vial.

3. Add one drop of stannous chloride solution. Shake and immediately compare with the phosphate color standards for cane juice, using the P_2O_5 illuminator. Note result. Then add another drop of stannous chloride solution, shake and make comparison again. Refer to the table for percentage of P_2O_5 in the sample.

4. If the color is too dark for comparison, return to Step 11 (Preparation of Sample) and transfer 5 ml. of the solution to a 50-ml. flask. Proceed with Steps 12 and 13 as before. Finally, multiply all values obtained from the table by 2 to obtain the correct percentage of P_2O_5.

5. If the color is too light for comparison, it will be necessary to prepare a fresh sample according to directions. In Step 11, transfer 20 ml. to a 50-ml. beaker and proceed. Finally, multiply values obtained from the table by 0.5 to obtain the true percentage of P_2O_5.

PERCENTAGE OF POTASH IN CANE LEAVES

(Green-weight basis)

50 ml. Reagent 8, N, 25 ml. filtrate, 5 ml. Reagent 10, K_2O

Green weight		1 ml.		.8 ml.		.6 ml.		.4 ml.		.3 ml.		.2 ml.	
Grams	Readings	2	3	2	3	2	3	2	3	2	3	2	3
.28		.27	.30	.33	.38	.45	.51	.67	.76	.89	1.01	1.34	1.52
.29		.26	.29	.32	.37	.43	.49	.65	.73	.86	.98	1.29	1.47
.30		.25	.28	.31	.35	.42	.47	.62	.71	.83	.94	1.25	1.42
.31		.24	.27	.30	.34	.40	.46	.61	.69	.81	.91	1.21	1.37
.32		.23	.27	.29	.33	.39	.44	.59	.66	.78	.88	1.17	1.33
.33		.23	.26	.28	.32	.38	.43	.57	.64	.76	.86	1.14	1.29
.34		.22	.25	.28	.31	.37	.42	.55	.62	.74	.83	1.10	1.25
.35		.22	.25	.27	.31	.36	.40	.54	.61	.71	.81	1.07	1.21
.36		.21	.24	.26	.30	.35	.39	.52	.59	.69	.79	1.04	1.18
.37		.20	.23	.25	.29	.34	.38	.51	.57	.68	.76	1.01	1.15
.38		.20	.22	.25	.28	.33	.37	.49	.56	.66	.74	.99	1.12
.39		.19	.22	.24	.27	.32	.36	.48	.54	.64	.73	.96	1.09
.40		.19	.21	.23	.27	.31	.35	.47	.53	.63	.71	.94	1.06

PERCENTAGE OF PHOSPHATE IN CANE LEAVES

(Green-weight basis)

50 ml. Reagent 8, 10 ml. filtrate, 8.5 ml. Reagent 4, P_2O_5

Green weight	Color Standard Tube No.							
Grams	1	2	3	4	5	6	7	8
.28	.057	.086	.114	.143	.171	.200	.229	.257
.29	.055	.083	.110	.138	.166	.193	.221	.248
.30	.053	.080	.107	.133	.160	.187	.213	.240
.31	.052	.077	.103	.129	.155	.181	.206	.232
.32	.050	.075	.100	.125	.150	.175	.200	.225
.33	.048	.073	.097	.121	.145	.170	.194	.218
.34	.047	.071	.094	.118	.141	.165	.188	.212
.35	.046	.069	.091	.114	.137	.160	.183	.206
.36	.044	.067	.089	.111	.133	.156	.178	.200
.37	.043	.065	.086	.108	.130	.151	.173	.195
.38	.042	.063	.084	.105	.126	.147	.168	.190
.39	.041	.061	.082	.103	.123	.144	.164	.185
.40	.040	.060	.080	.100	.120	.140	.160	.180

The Estimation of Nutrients in Alkaline Soils

Soils which are very alkaline or contain very large amounts of carbonates should not be analyzed for potash and phosphate by the regular R.C.M. procedures. There are several reasons which render data invalid when so obtained. The major difficulty is associated with side reactions which take place when the weakly acidified

soil extraction solution is brought in contact with the alkaline soil. Analyses of soils in this category for readily soluble nutrients, by extraction with extremely dilute acid solvents, are, at the very best, but little short of a compromise. However, modifications may be made to the standard procedure which compensate, to a degree, for the interfering alkalinity or excess of calcium and other carbonates.

*Rapid Estimation of Phosphate in Soils High in Calcium and Other Carbonates:**

Important: Use this procedure *only* when there is any effervescence upon the addition of N/2 hydrochloric acid solution to the soil in the regular procedure. Usually, soils of this type have a pH greater than 7.5.

Additional Equipment Required

1 gal. N/1 hydrochloric acid solution.
1 qt. 0.15 normal sodium hydroxide solution.
60 ml. methyl red indicator solution.
1 dropping bottle, pipette stopper with nipple, 60 ml.
1 pipette, 5 ml.

Procedure

During the course of the regular procedure for the Rapid Estimation of Phosphate in Soils, if there is any effervescence on the addition of N/2 hydrochloric acid solution to the 10 grams of soil, proceed as follows:

1. Filter immediately after swirling for ½ minute.
2. Transfer 5 ml. of the filtrate into a 100-ml. beaker by means of a 5-ml. pipette.
3. Add 2 drops of methyl red indicator, which imparts a pink or reddish color to the solution.
4. Then, with another 5-ml. pipette, add 5 ml. of the 0.15 normal sodium hydroxide solution and swirl the contents of the beaker.
5. A—If the pink color does not disappear, transfer a 10-ml. portion of the remaining filtrate to a 50-ml. beaker. Then continue with the usual treatment as in the procedure for the Rapid Estimation of Phosphate in Soils, beginning with Step 6.

B—If the pink color disappears, discard the remaining filtrate and extract 10 grams of the soil with a one-normal hydrochloric acid solution by swirling for ½ minute. Then immediately filter and continue from Step 5 in the regular procedure for the Rapid Estimation of Phosphate in Soils.

*Rapid Estimation of Potash in Soils High in Calcium:**

Important: Use this supplementary procedure *only when flocs or coarse aggregates appear* in the solution after Reagent 2, K_2O and Reagent 3, K_2O have been added and the vial shaken in the rotator.

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*A supplementary procedure. Refer to standard procedure for analytical details not included below (2).

Additional Equipment Required

1 pt. Reagent 14, Ca.
1 pkg. Whatman No. 2, 7-cm. filter paper.

Procedure

1. Proceed with Steps 1 to 5 as outlined in the procedure for the Rapid Estimation of Potash in Soils.

2. With the calibrated medicine dropper, transfer a 3-ml. portion of the filtrate to a clean vial.

3. Add 2 drops of Reagent 14, Ca and mix. Add 2 more drops of Reagent 14, Ca and mix. Finally, add another 2 drops of the reagent and mix so that to each ml. of filtrate, 2 drops of Reagent 14, Ca, are added.

4. Filter through Whatman No. 2, 7-cm. filter paper into another vial.

5. Using this final filtrate, continue with Steps 6 to 14, as described in the procedure for the Rapid Estimation of Potash in Soils.

6. If coarse aggregates or flocs are still formed in the final solution after 2 drops of Reagent 14, Ca have been added to each ml. of the filtrate, take another 3-ml. portion of the original filtrate and add 4 drops of Reagent 14, Ca to each ml. of filtrate. If flocs still appear in the final solution, add 6, 8 or more drops of Reagent 14, Ca to each ml. of the filtrate, as necessary, and continue as directed in Step 3 until the final solution presents a uniform turbidity.

7. Refer to the table which follows for soils high in calcium to obtain corrected results.

RAPID ESTIMATION OF POTASH IN SOILS

(Supplementary procedure for soils high in calcium)

Number of drops of Reagent 14, Ca added to each ml. of filtrate

Ratio Soil: Reagent	Reading	2		4		6		8		10		15		20		25		30	
		Per Cent	lb/ a-ft.	Per Cent	lb/ a-ft.	Per Cent	lb/ a-ft.	Per Cent	lb/ a-ft.	Per Cent	lb/ a-ft.	Per Cent	lb/ a-ft.	Per Cent	lb/ a-ft.	Per Cent	lb/ a-ft.	Per Cent	lb/ a-ft.
20g: 20 ml.	1	<.003	<75	<.003	<75	<.004	<100	<.004	<100	<.004	<100	<.004	<100	<.005	<125	<.005	<125	<.006	<150
	2	.003	75	.003	75	.004	100	.004	100	.004	100	.004	100	.005	125	.005	125	.006	150
	3	.004	100	.004	100	.005	125	.005	125	.005	125	.005	125	.006	150	.007	175	.008	200
	4	>.004	>100	>.004	>100	>.005	>125	>.005	>125	>.005	>125	>.005	>125	>.006	>150	>.007	>175	>.008	>200
15g: 20 ml.	1	<.004	<100	<.004	<100	<.005	<125	<.005	<125	<.005	<125	<.005	<125	<.006	<150	<.007	<175	<.008	<200
	2	.004	100	.004	100	.005	125	.005	125	.005	125	.005	125	.006	150	.007	175	.008	200
	3	.005	125	.006	150	.006	150	.006	150	.007	175	.007	175	.008	200	.009	225	.010	250
	4	>.005	>125	>.006	>150	>.006	>150	>.006	>150	>.007	>175	>.007	>175	>.008	>200	>.009	>225	>.010	>250
10g: 20 ml.	1	<.006	<150	<.007	<175	<.007	<175	<.007	<175	<.008	<200	<.009	<225	<.010	<250	<.011	<275	<.011	<275
	2	.006	150	.007	175	.007	175	.007	175	.008	200	.009	225	.010	250	.011	275	.011	275
	3	.007	175	.008	200	.008	200	.009	225	.009	225	.010	250	.011	275	.012	300	.013	325
	4	>.007	>175	>.008	>200	>.008	>200	>.009	>225	>.009	>225	>.010	>250	>.011	>275	>.012	>300	>.013	>325
7.5g: 20 ml.	1	<.010	<250	<.010	<250	<.011	<275	<.011	<275	<.012	<300	<.013	<325	<.014	<350	<.016	<400	<.017	<425
	2	.010	250	.010	250	.011	275	.011	275	.012	300	.013	325	.014	350	.016	400	.017	425
	3	.011	275	.011	275	.012	300	.012	300	.013	325	.015	375	.016	400	.018	450	.019	475
	4	>.011	>275	>.011	>275	>.012	>300	>.012	>300	>.013	>325	>.015	>375	>.016	>400	>.018	>450	>.019	>475
2.5g: 10 ml.	1	<.013	<325	<.013	<325	<.014	<350	<.015	<375	<.016	<400	<.017	<425	<.019	<475	<.021	<525	<.023	<575
	2	.013	325	.013	325	.014	350	.015	375	.016	400	.017	425	.019	475	.021	525	.023	575
	3	.015	375	.016	400	.017	425	.017	425	.018	450	.020	500	.022	550	.025	625	.027	675
	4	>.015	>375	>.016	>400	>.017	>425	>.017	>425	>.018	>450	>.020	>500	>.022	>550	>.025	>625	>.027	>675

RAPID ESTIMATION OF POTASH IN SOILS

(Supplementary procedure for soils high in calcium)

Ratio Soil: Reagent	Reading	Number of drops of Reagent 14, Ca added to each ml. of filtrate: 2		4		6		8		10	
		Per Cent	lb/ a-ft.	Per Cent	lb/ a-ft.	Per Cent	lb/ a-ft.	Per Cent	lb/ a-ft.	Per Cent	lb/ a-ft.
2.5g: 15 ml.	1	<.019	<475	<.020	<500	<.021	<525	<.022	<550	<.023	<575
	2	.019	475	.020	500	.021	525	.022	550	.023	575
	3	.022	550	.024	600	.025	625	.026	650	.027	675
	4	>.022	>550	>.024	>600	>.025	>625	>.026	>650	>.027	>675
2.5g: 20 ml.	1	<.027	<675	<.028	<700	<.030	<750	<.031	<775	<.033	<825
	2	.027	675	.028	700	.030	750	.031	775	.033	825
	3	.030	750	.031	775	.033	825	.035	875	.036	900
	4	>.030	>750	>.031	>775	>.033	>825	>.035	>875	>.036	>900
2.5g: 25 ml.	1	<.033	<825	<.035	<875	<.037	<925	<.039	<975	<.040	<1000
	2	.033	825	.035	875	.037	925	.039	975	.040	1000
	3	.037	925	.039	975	.041	1025	.043	1075	.046	1150
	4	>.037	>925	>.039	>975	>.041	>1025	>.043	>1075	>.046	>1150
2.5g: 30 ml.	1	<.039	<975	<.041	<1025	<.044	<1100	<.046	<1150	<.048	<1200
	2	.039	975	.041	1025	.044	1100	.046	1150	.048	1200
	3	.045	1125	.047	1175	.050	1250	.052	1300	.055	1375
	4	>.045	>1125	>.047	>1175	>.050	>1250	>.052	>1300	>.055	>1375
2.5g: 35 ml.	1	<.047	<1175	<.049	<1225	<.052	<1300	<.055	<1375	<.057	<1425
	2	.047	1175	.049	1225	.052	1300	.055	1375	.057	1425
	3	.052	1300	.055	1375	.058	1450	.061	1525	.064	1600
	4	>.052	>1300	>.055	>1375	>.058	>1450	>.061	>1525	>.064	>1600
2.5g: 40 ml.	1	<.053	<1325	<.056	<1400	<.059	<1475	<.062	<1550	<.065	<1625
	2	.053	1325	.056	1400	.059	1475	.062	1550	.065	1625
	3	.059	1475	.063	1575	.066	1650	.070	1750	.073	1825
	4	>.059	>1475	>.063	>1575	>.066	>1650	>.070	>1750	>.073	>1825

Rapid Estimation of Calcium in Cane Juice*

1. To a pint of fresh cane or crusher juice, add 2 heaping spoonfuls (small horn spoon) of R.C.M. cane juice preservative and shake well.

2. Allow the treated juice to stand for at least ½ hour.

3. Filter through Whatman No. 12, 15-cm. folded filter paper and collect at least 20 ml. of filtrate before proceeding.

4. By means of a 2-ml. Mohr pipette (for R.C.M. CaO), transfer a suitable aliquot—1.0 to 2.0 ml.—of the filtrate to a short-form shell vial (K_2O type).

5. Then add enough Reagent 13, Ca to bring the total volume to 3 ml., using a burette.

6. To the contents of the shell vial add 1 ml. of Reagent 14, Ca and immediately close the tube with the thumb and shake it with sufficient rapidity to insure 40 shakes in 8 seconds.

7. Let stand for *one minute.*

8. Make the reading as in the Rapid Estimation of Calcium in Soils and record the "2" and "3" readings registered by the *smallest* aliquots taken from the sample.

9. Refer to the table and obtain the concentration of calcium in terms of per cent CaO by volume or pounds of CaO per ton of juice in the original sample.

Example:

Aliquots	Readings	
1.0	1	
1.1	2—0.17 per cent	
1.2	2	
1.3	2	Avg. 0.18 per cent CaO,
1.4	2	or 34 lbs. per ton of juice.
1.5	3—.018 per cent	

10. In case the tested juice is higher (1 ml. = 3 reading), or lower (2 ml. = 2 reading) in CaO, dilute or concentrate the juice as follows:

To dilute: Mix thoroughly 10 ml. of filtered juice with 10 ml. of distilled water and proceed as described. When reading is made with this solution, refer to Table II.

To concentrate: Transfer 40 ml. of filtered juice into a 100-ml. beaker. Evaporate approximately to less than half of the original volume on an electric hot plate. Cool and carefully transfer the concentrated juice to a 25-ml. graduated cylinder and add washings from the beaker to the 20-ml. mark.

Mix well before using. Refer readings to Table III.

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*Refer to R.C.M. for calcium in soil for analytical details not included below (2).

RAPID ESTIMATION OF CALCIUM (CAO) IN CANE JUICE

(For Approximate Determination)

ml. aliquots of cane juice

Table I—Cane Juice

Readings		0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0
3	Per Cent	.26	.13	.087	.065	.052	.043	.037	.033	.029	.027	.025	.023	.021	.020	.018	.017	.016	.015	.015	.014
	lb per ton	4.81	2.41	1.61	1.20	0.96	0.80	0.69	0.60	0.54	0.50	0.46	0.42	0.39	0.36	0.34	0.32	0.30	0.29	0.27	0.26
2	Per Cent	.18	.090	.060	.045	.036	.030	.026	.023	.020	.019	.017	.016	.015	.014	.013	.012	.012	.011	.011	.010
	lb per ton	3.33	1.67	1.11	0.83	0.67	0.56	0.47	0.42	0.37	0.35	0.32	0.30	0.28	0.26	0.24	0.23	0.21	0.20	0.19	0.18

Table II—Diluted cane juice, 10 ml. cane juice + 10 ml. distilled water

3	Per Cent	.052	.047	.043	.040	.037	.035	.033	.031	.029	.027	.026
	lb per ton	0.96	0.88	0.80	0.74	0.69	0.64	0.60	0.57	0.54	0.51	0.48
2	Per Cent	.036	.033	.030	.028	.026	.024	.023	.021	.020	.019	.018
	lb per ton	0.67	0.61	0.56	0.51	0.47	0.44	0.42	0.39	0.37	0.35	0.33

Table III—Concentrated cane juice, 40 ml. cane juice conc. to 20 ml.

3	Per Cent	.015	.014	.013	.012	.011	.011	.010	.010	.009	.009	.008
	lb per ton	0.28	0.26	0.24	0.22	0.21	0.20	0.19	0.18	0.18	0.16	0.16
2	Per Cent	.011	.010	.010	.009	.008	.008	.008	.007	.007	.007	.006
	lb per ton	0.20	0.19	0.18	0.16	0.16	0.15	0.14	0.14	0.13	0.12	0.12

Rapid Estimation of Calcium in Irrigation or Other Water

Equipment Required

6 beakers, Pyrex glass, 400 ml.*
1 funnel rack, 10 hole.*
6 funnels, glass, 90 mm. dia.*
1 box Whatman No. 12, 15-cm. folded filter paper.*
1 cylinder, graduated, 100 ml.*
6 beakers, Pyrex glass, 250 ml.*
3 special pipettes, 2-ml. capacity (for Reagent 7, N).*
6 glass rods, 4½″ length.
1 dispensing burette, 250 ml.*
1 pkg. Munktell No. 3 (9- or 11-cm.) filter paper.*
1 pipette, Mohr 2 ml. (for CaO in soil).*
1 burette, 50 ml.*
1 dispensing bottle for Reagent 14, Ca with dropper calibrated to 1 ml.*
1 calcium illuminator.*
12 short-form shell vials.*
1 electric hot plate.*
6 funnels, glass, 65 mm. dia.*
6 beakers, Pyrex glass, 50 ml.*
1 lb. conc. nitric acid, special, in g.s.b.*
1 lb. conc. hydrochloric acid, special, in g.s.b.*
1 pt. Reagent 23, Ca in g.s.b.
1 gal. Reagent 13, Ca.*

General Procedure

Collect one gallon of water as representative of the sample to be analyzed. Thoroughly mix in bottle and filter about 250 ml. through a Whatman No. 12, 15-cm. folded filter paper.

1. Using a 100-ml. graduate, transfer 100 ml. of the filtered sample to a 250-ml. beaker and evaporate to dryness.

2. Add 2 ml. of conc. nitric acid and 2 ml. of conc. hydrochloric acid from a special pipette (for Reagent 7, N). Evaporate to dryness.

3. Add 2 ml. of conc. hydrochloric acid, using the same pipette. Evaporate to dryness. Allow residue to cool.

4. Add 2 ml. of Reagent 23, Ca. (If the same pipette is used, it must be thoroughly washed and at least partially dried. It may be more convenient to have 3 of these pipettes.)

5. Stir thoroughly by means of a glass rod and introduce from a dispensing burette 23 ml. of Reagent 13, Ca.

6. Mix well and filter through Munktell No. 3 (9- or 11-cm.) filter paper into a 50-ml. beaker.

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*Items included in other R.C.M. assemblies.

Approximate Determination

7. Using a 2-ml. Mohr pipette (for R.C.M.CaO), transfer successive aliquots of 0.1 to 1 ml. into potash vials.

8. Make the volume to 2 ml. by adding Reagent 13, Ca from a 50- or 25-ml. burette.

9. Add 1 ml. of Reagent 14, Ca and, closing the vial with the thumb, shake vigorously and with sufficient rapidity to insure 30 shakes in 7 seconds.

10. Let stand ½ minute and make readings as in R.C.M. calcium-in-soil procedure, recording the "2" and "3" readings registered by the smallest aliquots taken from the sample.

11. Refer to Table I and average the concentrations corresponding to the recorded readings.

Accurate Determination

12. Referring to the results of the approximate analysis, make dilutions, according to the following table:

Per Cent CaO	Dilution	For results
.0045 or less	Proceed without dilution	Refer to Table II
.0045—.0090	1 part sol'n to 1 part No. 13, Ca	Refer to Table III
.0090—.018	1 part sol'n to 3 parts No. 13, Ca	Refer to Table IV
.018 —.036	1 part sol'n to 7 parts No. 13, Ca	Refer to Table V

13. Transfer a suitable aliquot (1 to 3 ml.) to a potash vial and make up volume to 3 ml. with Reagent 13, Ca.

14. Add 1 ml. of Reagent 14, Ca; immediately close the vial with the thumb and shake with sufficient rapidity to insure 40 shakes in 8 seconds.

15. Let stand one minute and make readings as in the Rapid Estimation of Calcium in Soils, recording the "2" and "3" readings registered by the smallest aliquots.

16. Refer to the correct table for the concentration of calcium corresponding to the readings and take the average of the two.

17. In case the sample contains less than .0022 per cent of CaO and yet an accurate determination is required, start again from Step 1, but use a greater volume of sample (200, 300 or 500 ml.) and divide the final result by a factor obtained by dividing the volume of the sample by 100.

18. In case the sample contains more than .036 per cent of CaO, supplementary directions and a data chart may be prepared and furnished upon request.

RAPID ESTIMATION OF CALCIUM IN WATER

(Results expressed as per cent and pounds per million gallons)

Table I—Approximate Determination

Readings	Aliquots.	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
Reading 3	%	.065	.033	.022	.016	.013	.011	.0093	.0081	.0072	.0065
	lbs.	5425	2754	1836	1335	1085	918	776	675	601	543
Reading 2	%	.045	.023	.015	.011	.0090	.0075	.0064	.0056	.0050	.0045
	lbs.	3756	1920	1252	918	751	626	534	467	417	375

Table II—No Dilution

	Aliquots.	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8	1.9	2.0	2.2	2.4	2.6	2.8	3.0
Reading 3	%	.0065	.0059	.0054	.0050	.0046	.0043	.0041	.0038	.0036	.0034	.0033	.0030	.0027	.0025	.0023	.0022
	lbs.	543	492	451	417	384	359	342	317	300	284	275	250	225	209	192	184
Reading 2	%	.0045	.0040	.0038	.0035	.0032	.0030	.0028	.0026	.0025	.0024	.0023	.0020	.0019	.0017	.0016	.0015
	lbs.	375	334	317	292	267	250	234	217	209	200	192	167	159	142	134	125

Table III—1 Part Solution to 1 Part Reagent 13, Ca

Reading 3	%	.013	.012	.011	.010	.0093	.0087	.0081	.0076	.0072	.0068	.0065	.0059	.0054	.0050	.0046	.0043
	lbs.	1085	1002	918	835	776	726	676	634	601	568	543	492	451	417	384	359
Reading 2	%	.0090	.0082	.0075	.0069	.0064	.0060	.0056	.0053	.0050	.0047	.0045	.0041	.0038	.0035	.0032	.0030
	lbs.	751	684	626	576	534	501	476	442	417	392	376	342	317	292	267	250

Table IV—1 Part Solution to 3 Parts Reagent 13, Ca

Reading 3	%	.026	.024	.022	.020	.019	.017	.016	—	.014	—	.013	.012	.011	.010	.0093	.0087
	lbs.	2170	2003	1836	1669	1586	1419	1335	—	1169	—	1085	1002	918	835	776	726
Reading 2	%	.018	.016	.015	.014	.013	.012	.011	—	.010	—	.0090	.0082	.0075	.0069	.0064	.0060
	lbs.	1502	1335	1252	1169	1085	1002	918	—	835	—	751	684	626	576	534	501

Table V—1 Part Solution to 7 Parts Reagent 13, Ca

Reading 3	%	.052	.047	.043	.040	.037	.035	.033	.031	.029	.027	.026	.024	.022	.020	.019	.017
	lbs.	4340	3923	3589	3339	3088	2921	2754	2588	2421	2254	2170	2003	1836	1669	1586	1419
Reading 2	%	.036	.033	.030	.028	.026	.024	.023	.021	.020	.019	.018	.016	.015	.014	.013	.012
	lbs.	3005	2754	2504	2337	2170	2003	1920	1753	1669	1586	1502	1335	1252	1169	1085	1002

Rapid Estimation of Lime Requirement in Soils

Equipment Required

(Additional to that required for soil reaction [pH] determinations)

12 dishes, evaporating, Coors porcelain No. 3.
12 stirring rods, 3-inch length.
1 pestle.
1 gal. Reagent 25, Ca.

Procedure

1. Obtain about 300 grams of air-dried soil which has been passed through a 2-mm. sieve. Determine its pH value, using R.C.M. (LaMotte).

2. In each of eleven 150-ml. capacity porcelain evaporating dishes place 25 grams (5, 5-gram soil cups) of the air-dried soil sample.

3. Add the following amounts of Reagent 25, Ca to the dishes and mix well:

No. of dish	ml. of Reagent 25, Ca to be added	Application equiv. to lbs. of limestone per acre-foot of soil
1	5	1,000
2	10	2,000
3	20	4,000
4	30	6,000
5	40	8,000
6	50	10,000
7	65	13,000
8	80	16,000
9	100	20,000
10	125	25,000
11	150	30,000

Amounts greater than 50 ml. should be added in small portions of 50 ml. or less to avoid loss during mixing and to hasten evaporation. In these cases, evaporate the water as described below and then add more, followed by evaporation, until the prescribed amount has been applied.

4. Place the dishes in a warm, well-ventilated place, or preferably in the current of air from an electric fan. Mix occasionally.

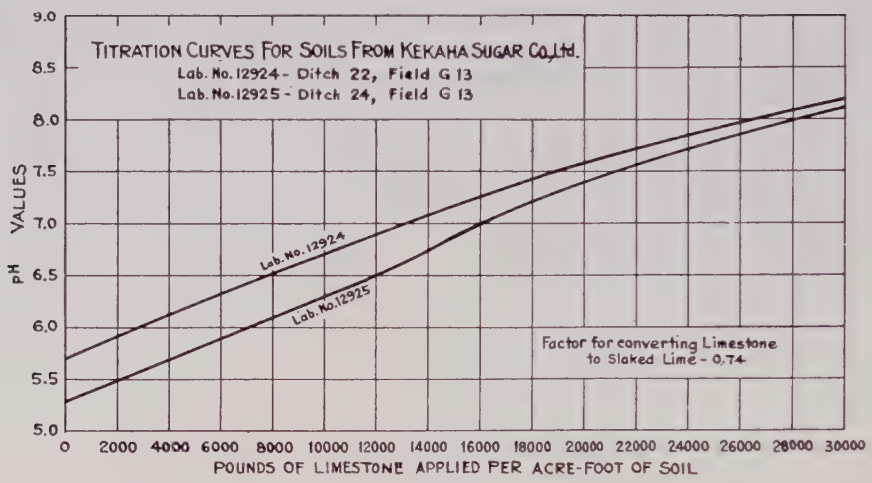
5. When the soils in the dishes are thoroughly dried, break up any large lumps with a pestle and mix well.

6. Determine the pH values on the 11 soils by R.C.M.

7. Plot on graph paper the points corresponding to the pH values against the respective treatments (expressed as pounds of limestone per acre-foot of soil) and connect these points by a smooth curve. This latter is the titration curve of the soil.

8. The amount of pure limestone required per acre to bring an acre-foot depth of soil to any desired pH within the range covered by the determination can be found by interpolation.

9. When sources of lime other than pure limestone are to be used in the field, it will be necessary to multiply the values on the curve by a factor, depending upon the composition of the material. Also, to bring a greater depth of soil to the desired pH, it is necessary to multiply the value by the depth in question, expressed in feet.



Titration curve for lime requirement in soil determination.

Rapid Determination of Replaceable Magnesium in Soils

Equipment Required

1 metal soil cup, 10 gram.*
1 metal soil cup, 5 gram.*
1 metal soil cup, 2½ gram.*
1 spatula, stainless steel, 4-inch blade.*
12 flasks, Erlenmeyer Pyrex, 125 ml.*
12 beakers, Pyrex glass, 100 ml.*
1 funnel rack, 10 hole.*
12 funnels, glass, 65 mm. dia.*
1 box Whatman No. 12, 15-cm. folded filter paper.*
1 dispensing burette, 250 ml. (with cover).*
1 pipette, Mohr 1 ml., graduated to 0.01 ml.
1 pipette, Mohr 10 ml., graduated to 0.1 ml.
12 vials, shell, tall-form.*
12 rubber stoppers, No. 00.*
1 dispensing bottle for Reagent 20, Mg. Same type as for Reagent 2, K_2O but with dropper graduated to ½ ml.
1 dispensing bottle for Reagent 21, Mg. Same type as for pH indicator solutions, but paraffined and with dropper graduated to 1 ml.
1 set magnesium-in-soil color standards (in box with rack, etc.).
1 phosphate illuminator.*
1 vial block.*
1 gal. Reagent 13, Ca.*
½ pt. Reagent 20, Mg.
1 pt. Reagent 21, Mg.

*Material included in other R.C.M. assemblies.

Procedure

1. Extract 10 grams of soil with 50 ml. of Reagent 13, Ca for one minute.
2. Filter through Whatman No. 12, 15-cm. folded filter paper.
3. Transfer into P_2O_5 vials suitable and consecutive aliquots of the extract. (.1, .2, .3, .4, .5 ml., etc., for soils containing about 0.2 per cent of replaceable MgO and 1.0, 1.25, 1.50, 1.75, 2.00 ml., etc., for soils containing about 0.02 per cent MgO.)
4. Add to each vial enough Reagent 13, Ca to bring the volume up to about one inch from the top.
5. Add ½ ml. of Reagent 20, Mg to the first vial and shake by inverting the tube 2 to 3 times.
6. Add 1 ml. of Reagent 21, Mg and shake again until the color developed is uniform throughout the vial.
7. Flip out about 1 ml. of the solution and stopper the vial with a No. 00 rubber stopper.
8. Immediately compare with the magnesium color standards on a P_2O_5 illuminator and record the reading in terms of the standard tube number.
9. Repeat Steps 5—8 with the remaining vials.
10. Refer to the data chart and record the percentages corresponding to the standard tube numbers. Up to this point, the recorded data will appear as in the following example:

Lab. No.	Extraction	Aliquot	Reading	Per Cent
12772	10-50	.1	3-4	.13—.27
		.2	5-6	.20—.33
		.3	5-6	.13—.22
		.4	6-7	.17—.23

11. Now select the maximum figure from the left column and the minimum figure from the right column and average the two. The result indicates the percentage concentration of replaceable MgO in the sample. Convert to pounds per acre-foot by multiplying by 25,000.

The concentration of replaceable MgO in the above sample is 0.21 per cent, or 5250 pounds per acre-foot.

12. Should one of the aliquots match exactly a standard, then take that result as the concentration of MgO in the sample and see whether or not this percentage agrees with that obtained by averaging, as in Step 11. If it does not, then repeat this particular aliquot to see whether or not the reading obtained is in error.

Example:

Lab. No.	Extraction	Aliquot	Reading	Per Cent	Avg.
12890	10-50	.1	3-4	.13—.27	
		.2	4-5	.13—.20	
		.3	5-6	.13—.22	.17
		.4	6	.17	
		.5	6-7	.13—.20	

In the above example, a .4-ml. aliquot gave a color matching standard No. 6 exactly, giving a concentration of .17 per cent. Averaging .13 per cent and .20 per cent also gives a concentration of .17 per cent.

13. Where the MgO concentration of a soil does not fall within the chart, the specimen may be analyzed by varying the extraction and multiplying the final result by the corresponding factor.

Soil (gm.)	Extraction sol'n (ml.)	Factors
10	50	1
5	50	2
2.5	50	4
20	50	½
30	50	⅓
40	50	¼
50	50	⅕

Precautions:

(a) The vials must be free of acids, since acids cause the color to disappear.

(b) Addition of Reagent 21, Mg causes an evolution of ammonia gas and hence determinations of ammoniacal nitrogen should be completed before determinations of MgO are undertaken.

(c) Reagent 20, Mg is unstable and for this reason should be kept in the dark when not in use. Even if kept in the dark, it should be replaced at least once a month.

(d) The standards fade gradually and should be renewed at intervals of about one month.

RAPID DETERMINATION OF MAGNESIA (MgO) IN SOILS

Per Cent and Pounds Per Acre-foot of Magnesia (MgO)

Standard No.	Aliquots in ml.																				
	.1	.2	.3	.4	.5	.6	.7	.8	.9	1.0	1.25	1.50	1.75	2.00	2.50	3.00	3.50	4.00	4.50	5.00	6.00	7.00
1	.013	.0067	.0045	.0033	.0027	.0022	.0019	.0017	.0015	.0013	.0011	.0009	.0008	.0007	.0005	.0004	.0004	(Less than .0004%)				
	325	168	113	83	68	55	48	43	38	33	28	23	20	18	13	10	10	(Less than 10 lb)				
2	.067	.033	.023	.017	.013	.011	.0096	.0084	.0074	.0067	.0054	.0045	.0038	.0033	.0027	.0022	.0019	.0017	.0015	.0013	.0011	.0009
	1675	825	575	425	325	275	240	210	185	168	135	113	95	83	68	55	48	43	38	33	28	23
3	.13	.067	.045	.033	.027	.022	.019	.017	.015	.013	.011	.0089	.0076	.0067	.0054	.0045	.0038	.0033	.0030	.0027	.0022	.0019
	3250	1675	1125	825	675	550	475	425	375	325	275	223	190	168	135	113	95	83	75	68	55	48
4	.27	.13	.089	.067	.054	.045	.038	.033	.030	.027	.021	.018	.015	.013	.011	.0089	.0077	.0067	.0060	.0054	.0045	.0038
	6750	3250	2225	1675	1350	1125	950	825	750	675	525	450	375	325	275	223	193	168	150	135	113	95
5	.40	.20	.13	.10	.080	.067	.057	.050	.045	.040	.032	.027	.023	.020	.016	.013	.012	.010	.0089	.0080	.0067	.0057
	10000	5000	3250	2500	2000	1675	1425	1250	1125	1000	800	675	575	500	400	325	300	250	223	200	168	143
6	.67	.33	.22	.17	.13	.11	.095	.084	.074	.067	.054	.045	.038	.033	.027	.022	.019	.017	.015	.013	.011	.0096
	16750	8250	5500	4250	3250	2750	2375	2100	1850	1675	1350	1125	950	825	675	550	475	425	375	325	275	240
7	1.00	.50	.33	.25	.20	.17	.14	.13	.11	.10	.080	.067	.057	.050	.040	.033	.029	.025	.022	.020	.017	.014
	25000	12500	8250	6250	5000	4250	3500	3250	2750	2500	2000	1675	1425	1250	1000	825	725	625	550	500	425	350
8	1.34	.67	.45	.33	.27	.22	.19	.17	.15	.13	.11	.089	.076	.067	.054	.045	.038	.033	.030	.027	.022	.019
	33500	16750	11250	8250	6750	5500	4750	4250	3750	3250	2750	2225	1900	1675	1350	1125	950	825	750	675	550	475

Rapid Determination of Magnesia (MgO) in Water

Equipment Required

12 vials, shell, tall-form.*
1 pipette, Mohr 10 ml., graduated to 0.1 ml.
1 box Whatman No. 12, 15-cm. folded filter paper.*
6 beakers, Pyrex glass, 400 ml.*
1 funnel rack, 10 hole.*
6 funnels, glass, 90 mm. dia.*
1 dispensing bottle, for Reagent 22, Mg. Same type as for Reagent 2, K_2O, but with dropper graduated to ½ ml.
1 dispensing bottle, for Reagent 21, Mg. Same type as for pH indicator solutions, but paraffined and with dropper graduated to ½ ml.
1 set magnesium-in-water color standards (in box with rack, etc.).
1 phosphate illuminator.*
1 vial block.*
1 gal. distilled water.
½ pt. Reagent 22, Mg.
1 pt. Reagent 21, Mg.

General Procedure

Collect one gallon of water as representative of the sample to be analyzed. Thoroughly mix in bottle. Filter about 250 ml. through a Whatman No. 12, 15-cm. folded filter paper.

1. Transfer, by means of a 10-ml. Mohr pipette, successive aliquots (as indicated on the data chart) of the filtered sample into P_2O_5 vials.

2. Make up volume to about one inch from the top of the vial with distilled water.

3. Add ½ ml. of Reagent 22, Mg to the first vial and shake by inverting the tube 2 or 3 times.

4. Add ½ ml. of Reagent 21, Mg and shake again until the color developed is uniform throughout the vial.

5. Immediately compare with the magnesium-in-water color standards on a phosphate illuminator and record the reading in terms of the standard tube number.

6. Repeat Steps 3—5 with the remaining vials.

7. Refer to the data chart and record the concentration of MgO as percentage or as pounds per million gallons, or both, depending upon the data required.

8. Now, average the maximum figure from the left column and the minimum figure from the right column, as in the method for magnesium in soils.

*Material included in other R.C.M. assemblies.

Example:

Aliquot in ml.	Reading	Per Cent	lb/mil.gal.
1	1-2	.0007—.0020	56—167
2	1-2	.0010—.0017	84—140
3	2-3	.0007—.0011	56— 93
4	3-4	.0008—.0012	70— 98
5	4-5	.0009—.0012	78—100
6	4-5	.0008—.0010	65— 84
7	5-6	.0009—.0010	72— 88
		Average .0010	84

9. Specimens containing over 300 pounds of MgO per million gallons may be analyzed by making a suitable dilution, using distilled water and multiplying the final result by a corresponding factor.

Parts of sample	Parts of distilled water	Factor
1	1	2
1	2	3
1	3	4
1	4	5

Precaution: Reagent 22, Mg is unstable and should be kept in the dark when not in use. Change the solution at intervals of about one month.

MAGNESIA (MgO) IN WATER

Per cent and pounds per million gallons

Standard No.	Aliquots in ml. 1	2	3	4	5	6	7
1	.0007	.0003	.0002	.0002	.0001	.0001	.0001
	56	28	19	14	11	9	8
2	.0020	.0010	.0007	.0005	.0004	.0003	.0003
	167	84	56	42	33	28	24
3	.0033	.0017	.0011	.0008	.0007	.0006	.0005
	279	140	95	70	56	47	40
4	.0047	.0023	.0016	.0012	.0009	.0008	.0007
	391	195	130	98	78	65	56
5	.0060	.0030	.0020	.0015	.0012	.0010	.0009
	502	251	167	126	100	84	72
6	.0074	.0037	.0025	.0018	.0015	.0012	.0011
	614	307	205	154	123	102	88
7	.0087	.0043	.0029	.0022	.0017	.0014	.0012
	725	363	242	181	145	121	104
8	.0100	.0050	.0033	.0025	.0020	.0017	.0014
	837	419	279	209	167	140	120

EXPLANATION OF PLATE I

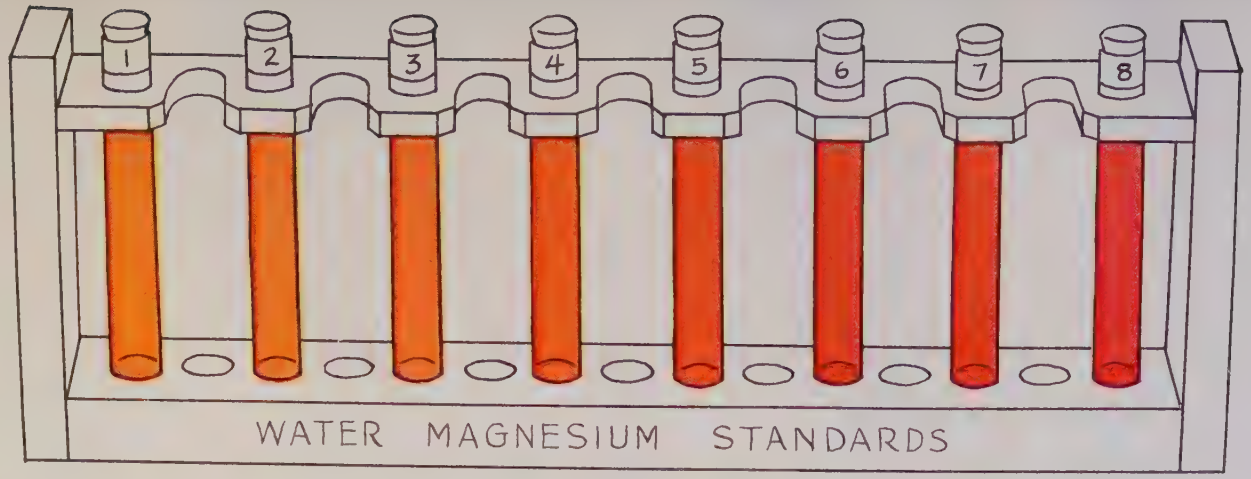
Magnesium Standards for Water Analysis

The principle followed in this set of standards is similar to other R.C.M. colorimetric detail. The tubes shown are placed in stationary positions in the rack in their sequence of color intensity. Unknown solutions in open vials are placed in the notched intervening spaces for comparison. The sealed tubes of color standards are numbered progressively from one to eight. Reference is made to a suitably prepared table for analytical values. The colored components of these standards have been prepared from mutually miscible inorganic constituents. They are chemically stable and fast to light.

Magnesium Standards for Soil Analysis

The arrangement of the standards, their coding and analytical usage are similar to those described above. At present, aniline dyes are employed as sources of color. It is necessary, therefore, to renew them occasionally.

Full details of preparation, standardization and care of standards appear in the text.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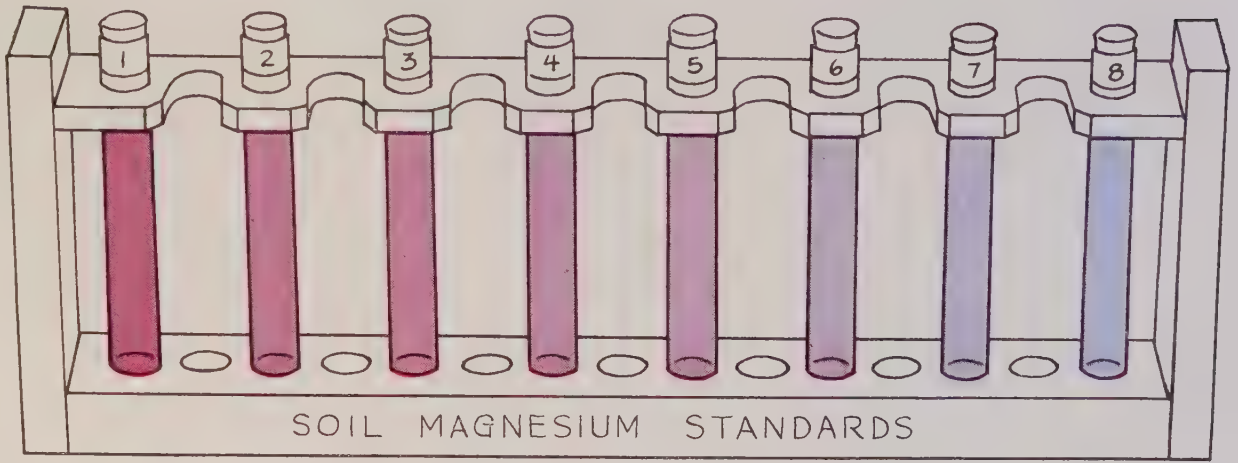
WATER MAGNESIUM STANDARDS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SOIL MAGNESIUM STANDARDS

The Rapid Determination of Chlorides (Salt) in Water

The procedure described below for the determination of chlorides in water does not depart in any essential details from standard laboratory practice. The method has been modified so as to render it comparable to other R.C.M.

A method, previously described by Denny (1), suggested the practicability of devising a similar procedure.

Equipment Required

6 beakers, Pyrex glass, 400 ml.*
1 funnel rack, 10 hole.*
6 funnels, glass, 90 mm. dia.*
1 box Whatman No. 12, 15-cm. folded filter paper.*
1 pipette, volumetric, 10 ml.*
1 pipette, volumetric, 5 ml.*
1 graduated cylinder, 50 ml.
2 casseroles, glazed porcelain, 90 mm. dia.
2 stirring rods, 3½" length.*
1 burette, 50 ml.*
1 pipette, special for Reagent 6, N—1 ml.*
1 gal. distilled water.*
½ pt. Reagent 26, Cl in g.s.b.
2 liters Reagent 27, Cl in 2½ liter g.s.b. (Amber bottle, or painted black on outside, leaving a narrow streak of unpainted surface.)

General Procedure

Collect one gallon of water as representative of the sample to be analyzed. Mix well and filter about 250 ml. through a Whatman No. 12, 15-cm. folded filter paper.

1. By means of a 10-ml. volumetric pipette, transfer 10 ml. of the filtered sample into a 200-ml. casserole.
2. Add 40 ml. of distilled water from a graduate.
3. Using a 1-ml. special pipette (for Reagent 6, N), add 1 ml. of Reagent 26, Cl.
4. Titrate with Reagent 27, Cl from a 50-ml. burette, stirring the solution vigorously at the same time. (Toward the end of the titration, Reagent 27, Cl should be added slowly, drop by drop, until a definite change in color results. To be able to determine the color change accurately, a blank should always be run at the beginning, using 50 ml. of distilled water, one ml. of Reagent 26, Cl and one drop of Reagent 27, Cl. This is the color to which all samples should be titrated.)
5. Read to the nearest .05 ml. the volume of Reagent 27, Cl required for titration.
6. Refer to the chart and convert the burette reading into percentage of Cl and pounds of Cl per million gallons.

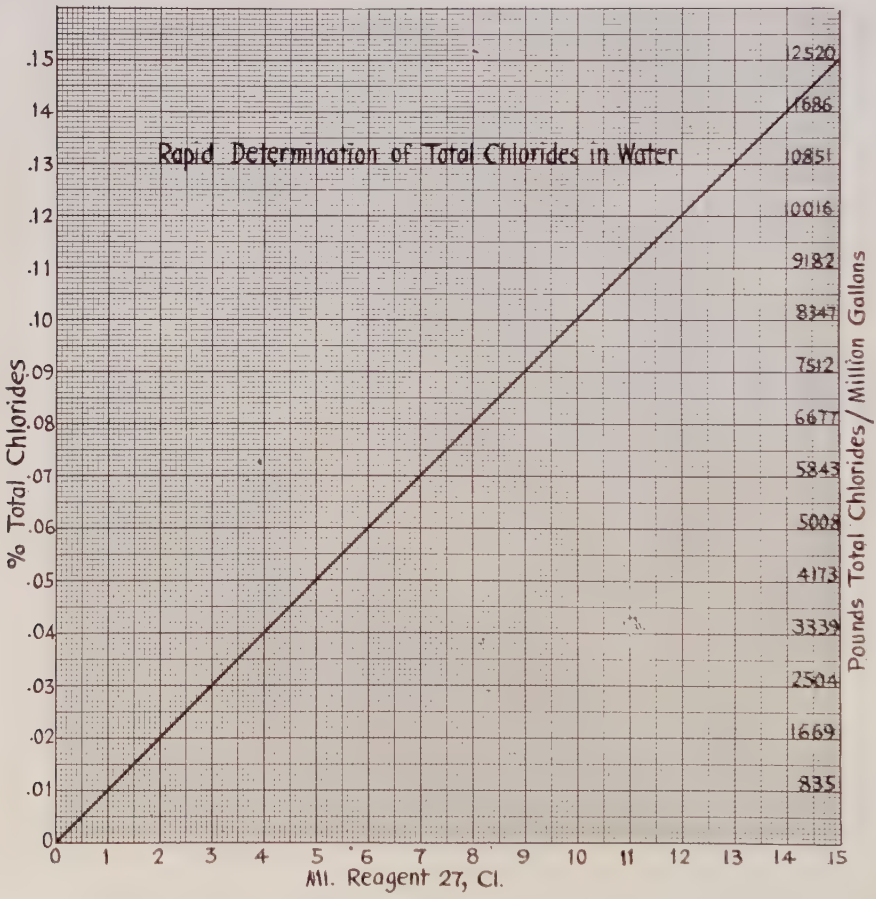
*Items included in other R.C.M. procedures.

7. A sample containing more than .15 per cent may be analyzed by taking a 5-ml. aliquot (plus 45 ml. of distilled water) and multiplying the result by 2.

8. In case a sample contains less than .02 per cent, a volume larger than 10 ml. should be taken and treated according to the following table:

ml. Aliquot*	ml. Distilled water	ml. Reagent 26, Cl	Divide result by:
20	30	1	2
30	20	1	3
40	10	1	4
50	0	1	5
100	0	2	10

9. To convert concentrations of Cl to NaCl, multiply by 1.649.



Graph for determination of total chlorides (salt) in water.

*For the sake of accuracy, whenever possible, take a volume large enough to require at least 2 ml. of Reagent 27, Cl. A 50-ml. graduate may be used to measure aliquots greater than 20 ml.

A Refinement in the Determination of Potash in Soil Where Low Concentrations of the Nutrient Prevail

The method described below is a modification of the standard R.C.M. procedure. At the suggestion of W. W. G. Moir, Agricultural Technologist, American Factors, Ltd., the decision was reached to introduce a refinement whereby greater accuracy could be realized in estimating the potash content of soils in regions where low concentrations of the nutrient were known to prevail. The modified method was developed by P. E. Chu, Assistant Chemist, in collaboration with the author.

Additional Equipment Required

1. An extra sliding, perforated cover for the potash illuminator upon which has been mounted a 3-hole guide block 1¼″ x 3⅝″ horizontal dimensions x 2⅛″ in height. Openings in the block are made with an 11/16″ bit and are placed so that the centers coincide with similar but slightly smaller openings in the sliding cover.

2. A revised, lined chart, to be substituted in place of the one regularly used under the opal window of the illuminator. The new chart is ruled with 4 separate bands of straight lines instead of the 3 sets heretofore used. Each series differs from the one adjoining. The intensity of the bands begins with a heavy black series and recedes in 4 distinct steps to a group of faint green lines. (Refer to the previously published article for general details [2].) Illustrations of the new chart and the modified guide block slide-cover appear herein.

Procedure

In soils for which the potash content was previously recorded as "low," <.003 per cent and <75 lbs. K_2O per acre-foot, a more sensitive test has been developed, the details of which are given below. It enables the operator to analyze soils which carry as little as 20 pounds of K_2O per acre-foot. Values up to 80 pounds per acre-foot in increments not exceeding variations of 12 pounds may be determined by the same procedure.

1. Extract 7.5 grams of soil with 20 ml. of Reagent 1, K_2O as heretofore.

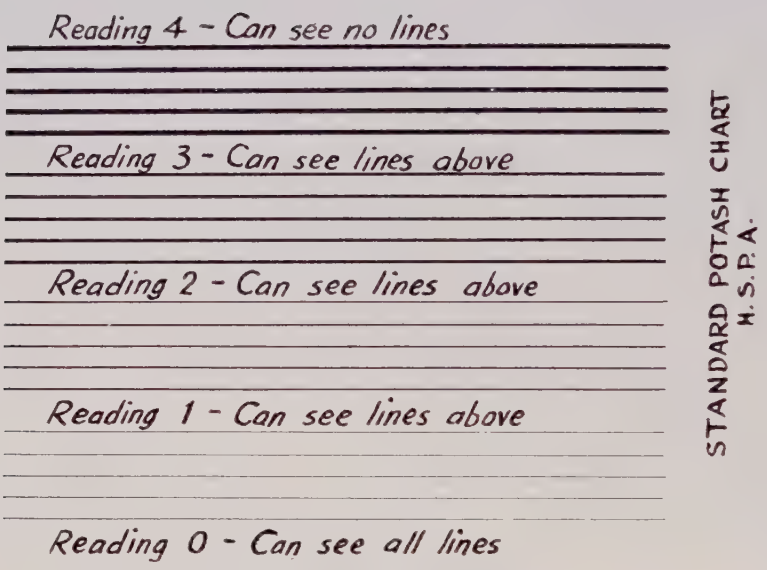
2. With a calibrated medicine dropper, transfer 1-ml. portions of the filtrate to the bottom of each of *four* vials (short-form, shell vials). It is essential to employ 4 vials in the test. If the amount of filtrate obtained is not sufficient, make duplicate extractions until the required volume is reached.

3. Add the usual amounts of Reagent 2, K_2O and Reagent 3, K_2O and proceed as directed in Steps 7, 8, 9 and 11 of the standard potash method. Use all the slots of the potash rotator.

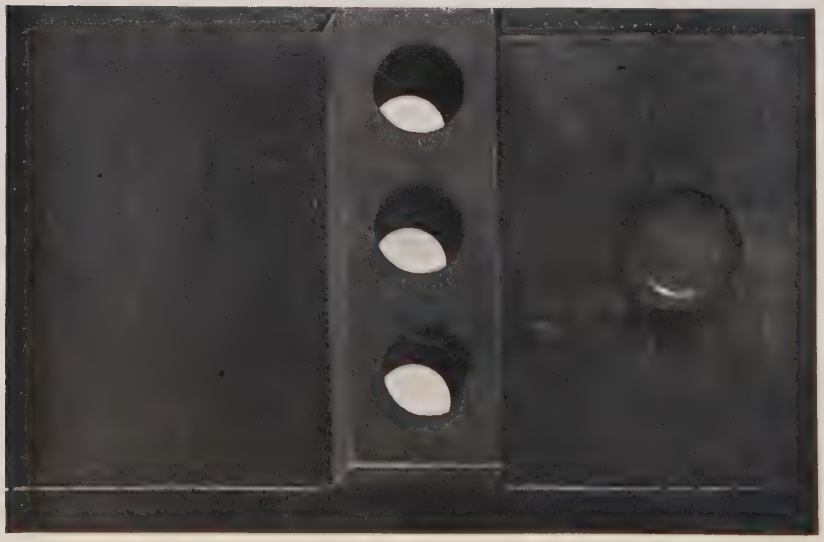
4. As soon as the rotating operation has been completed, remove the vials and, holding one of the vials in the left hand, pour the contents of the remaining three into it, letting each vial drain for 4 seconds.

5. Stopper the filled vial with the middle finger, resting its lower end on the thumb. Mix by inverting the tube 4 times in about 5 or 6 seconds.

6. Allow the vial to stand for about 30 seconds and then transfer it to the center slot of the potash illuminator.



New standard potash chart.



New slides for potash illuminators.

7. Place the openings over the heaviest lines and take readings as in the regular R.C.M. A faint set of green lines has been added to the potash chart, thereby necessitating a new reading of "0," making 5 readings in all, i.e., 4, 3, 2, 1 and 0. The reading is "0" when *all* of the lines can be seen. The other readings remain as explained in Step 13 of the standard R.C.M. procedure for potash in soil.

8. Refer to the table which follows to ascertain the percentage and pounds per acre-foot data for soils analyzed by this modified procedure. In case a reading of "0" is obtained, prepare fresh extracts, using 12½ grams of soil to 20 ml. of Reagent 1, K_2O, or 30 grams of soil to 30 ml. of Reagent 1, K_2O, as shown in the accompanying table.

DETERMINATION OF POTASH IN SOIL WHERE LOW CONCENTRATIONS OF THE NUTRIENT PREVAIL

(For high-column test solutions)

Ratio				
Gm. Soil	ml. Reag. 1, K_2O	Readings	Per cent K_2O	lb K_2O per acre-foot
30	30	0	<.0008	<20
		1	.0008	20
		2	.0010	25
		3	.0012	30
		4	>.0012	>30
12.5	20	0	<.0013	<32
		1	.0013	32
		2	.0016	40
		3	.0019	48
		4	>.0019	>48
7.5	20	0	<.0022	<55
		1	.0022	55
		2	.0027	67
		3	.0032	80
		4	>.0032	>80

The Preparation of Reagents Not Described in the Previous Article—Reagents Used in Procedures Discussed in This Paper

Cane Juice Preservative:

In a study of the composition of crusher juice or of small amounts of cane juice obtained from experiments or from the field, it is frequently necessary to put aside a series of collections for hours, or even for days, to await a favorable opportunity for the analyses.

Formalin, in these cases, cannot be made use of because of interfering chemical reactions in subsequent analytical treatment of the juice. A number of other preservatives are equally objectionable because of dilution, interference with analysis or for other reasons. Research led to the selection of a preserving mixture consisting of benzoic and salicylic acids with sodium borate. Its use, at the rate of 4 grams to one liter of juice, effectively inhibits fermentation, prevents mold formation, clarifies the juice, does not dilute it or add to its liquid volume and occasions no

objectionable side reactions with the reagents employed for the determinations of nitrogen, phosphate, and potash.

The use of the preservative in connection with the determination of nitrogen in juices suggested the possibility that, owing to clarifying action of the preserving compound, colloidal protein matter in the juice may be precipitated and thus result in finding lower nitrogen values in the final analysis. The matter was investigated by Mr. Nishimura. Using 4 different juice types from various sources at variable intervals, he determined the total nitrogen content of each fresh specimen, recorded the data and added the regular increments of preservative per unit volume of juice to each of the residues. The containers were then closed with airtight seals. At intervals, over a maximum period of about 10 weeks, he withdrew samples from each of the preserved juices and reanalyzed them. In every case the reanalysis was made on clear, screened juice, the product having become clarified within a few hours after adding the preservative. His data indicate that the nitrogen values remain unchanged, irrespective of the addition of preservative and that time and the process of clarification, apparently, exert no appreciable influence upon the accuracy or reliability of the nitrogen determination. His data follow:

	Fresh Juice	Juice Preserved by R.C.M. Compound					
Sample	% N	% N	% N	% N	% N	% N	% N
I	4/ 3/36 .011	4/ 6/36 .0105	4/ 9/36 .010	4/11/36 .0105	4/13/36 .010		
II	4/ 7/36 .0125	4/ 8/36 .012	4/ 9/36 .013	4/11/36 .013	4/13/36 .013		
III	4/15/36 .028	4/18/36 .026	4/20/36 .027	4/22/36 .026	4/24/36 .027	6/24 .026	
IV	2/19/36 .020	3/ 2/36 .019	3/ 5/36 ...	3/10/36 .021	....	....	

Preparation of Preservative: Weigh out 2 kilograms each of benzoic acid and salicylic acid and one kilogram of sodium borate. These materials may be either of U.S.P. or C.P. grades. Mix the powders and grind them thoroughly, using a wedgewood mortar and pestle. A preliminary grinding of the 2 acids in the mortar will facilitate subsequent incorporation of the sodium borate. The grinding operations should be conducted in an effective hood because of the irritating properties of the organic acids to the skin, but more so to their pronounced irritation of the nasal passages. Violent sneezing may be induced if this precaution is not observed.

Reagent 20, Mg:

Dissolve 0.01 gm. p-nitrobenzene azoresorcinol in 2 ml. of a one per cent NaOH solution and make the volume up to 200 ml. with distilled water.

Reagent 21, Mg:

Take 120 ml. of 50-50 sodium hydroxide solution and make the volume up to 250 ml. with distilled water, free from carbon dioxide.

Reagent 22, Mg:

Dissolve 0.15 gm. Titan Yellow in 100 ml. of a solution consisting of equal volumes of methyl alcohol and distilled water.

Reagent 23, Ca:

A solution containing 36 per cent acetic acid, C.P. in distilled water.

Normal HCl:

A solution consisting approximately of 11 parts of distilled water and one part of concentrated hydrochloric acid (by volume). Standardize by titration against 1/10 Normal NaOH.

Reagent 25, Ca: (0.04 Normal Limewater)

Place 200 grams slaked lime ($Ca[OH]_2$) in a 2½-liter glass-stoppered bottle. Add somewhat less than 2000 ml. of distilled water, free from carbon dioxide, and shake. Let stand at least 2 days with occasional agitation. Filter quickly through Whatman No. 12 filter paper (folded) and adjust to 0.04 N, using distilled water, free from CO_2.

Reagent 26, Cl:

Dissolve 5 grams potassium chromate, C.P. (K_2CrO_4) in water. Add a dilute solution of silver nitrate ($AgNO_3$) until a slight and permanent red precipitate is produced. Filter and make volume to 100 ml. with distilled water.

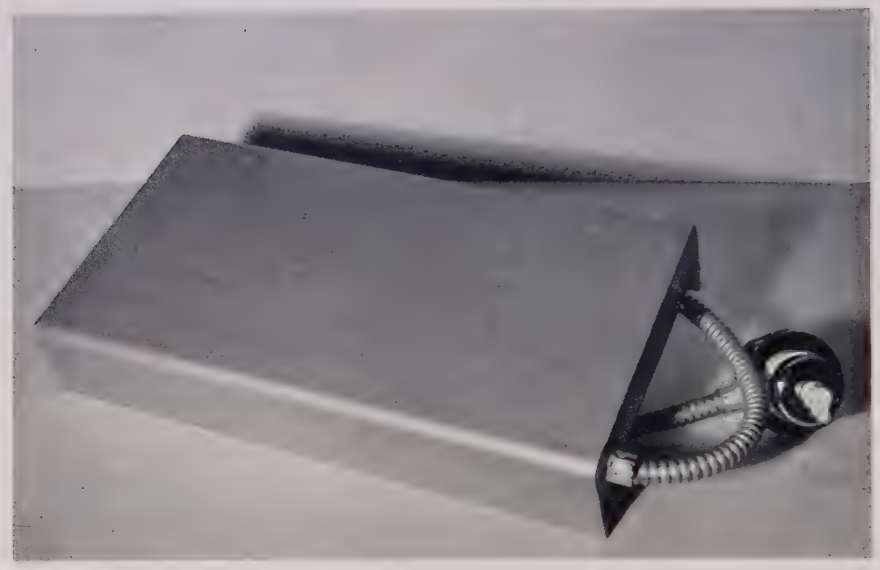
Reagent 27, Cl: (0.02819 Normal Silver Nitrate)

Dissolve 4.791 gm. silver nitrate, C.P. ($AgNO_3$) in distilled water and make volume to 1000 ml. (1 ml. = 1 mg. Cl). Check by titration against a standard solution of sodium chloride.

The Modern R.C.M. Laboratory

Elsewhere in this article there appears a building and fixture specification which may be used as a guide in the construction of an efficient and inexpensive laboratory for conducting rapid chemical analyses. The building plan and fixture detail represent the results of the study and experiences of the plantation and Experiment Station staffs of the Hawaiian sugar industry for a period in excess of 4 years.

Attention of the prospective builder is called to advantages to be gained by including in the building the cabinets, cupboards and utility table which are specified and illustrated. These furnishings permit the proper storage and care of reagents and accessories; they contribute to the neatness of the laboratory and permit the analysts to conduct their work with precision, in proper order and with a minimum of waste motion. The utility table should be mounted on casters or small rubber-tired wheels. Of still greater importance to the proficiency of chemical-analytical manipulations and to the preservation of the balance, electrical fixtures and laboratory ironware against corrosion, is the size, arrangement and efficiency of the hood. Wherever possible, select a location for the hood in a corner of the building remote from the direction of the prevailing winds. The chimney should be constructed entirely of smooth wood (under no circumstances use metal). Joints should be mitered or, preferably, dovetailed and securely fastened in place with asphaltic or similar cement. Leaks in the chimney seriously reduce the draft. The canopied cover atop the chimney should be ample to prevent the entrance of rain and roosting of birds without sacrificing the draft. The floor of the hood should consist of transite board, or other silicate cement-like material which is impervious to heat, steam and hot acid fumes. Electrical outlets from the power line or house current should terminate adjacent to,



R.C.M. electric hot plate.

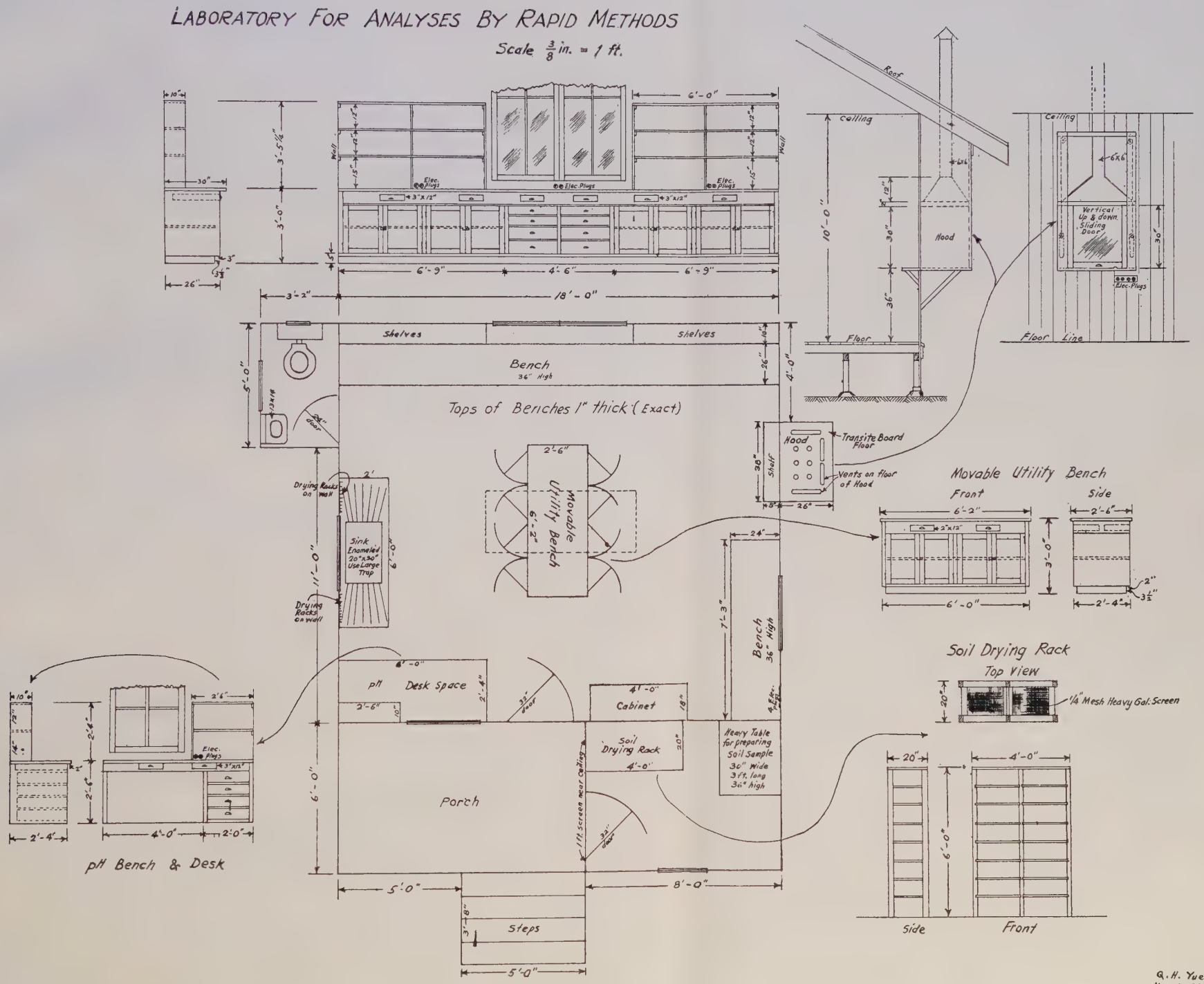
but *not* inside of the hood enclosure. The dimensions given for the hood, if followed, will insure convenient spacing of the hot plate (12″ x 24″) and several Type "H" heaters for use in nitrogen digestion work. An up-and-down sliding glass door should close the hood from the laboratory.

Photographs of several of the recently built R.C.M. laboratories are shown on pages 181 to 186.

An Electric Hot Plate Suitable For R.C.M.

Stock hot plates of conventional design and construction are not, as a rule, entirely satisfactory for R.C.M. work. This is true even of the 3-heat types which provide controllable low, medium and high temperatures. The major objection applies to the low heat. It is seldom sufficiently low.

The author prepared specifications for an electrically heated instrument, about 50 of which are now in service. The plate, illustrated herein, is a plain, rectangular, flat-top affair provided with easily accessible, replaceable, electrically insulated and fume-protected wire-wound heating elements. It operates on 110 volts. Internal electrical connections are arranged when the switch is set on "low" to produce a minimum temperature of about 80° C. and a maximum of about 103° C. in the beakers of test solution resting on the plate surface directly above the heating units. The variability in temperature limits is governed, of course, by the nature of the liquid in the containers and by the use or absence of watch glass covers. Evaporation of test solutions to complete dryness may be obtained satisfactorily without bumping, boiling or sputtering of residues as they approach a pasty condition.



Plan and fixture details for the construction of R.C.M. laboratory.

The entire plate assembly may be obtained from the manufacturer in lots of ten for $40.00 each. Data of specifications and performance tests of this plate follow:

Dimensions: 24" x 12" x 4½".
Weight: 60 pounds.
Capacity: 50 beakers of 50-ml. capacity each.
36 beakers of 100-ml. capacity each.
18 beakers of 400-ml. capacity each.
15 beakers of 600-ml. capacity each.
Heats: Three—High, medium, and low.
Line: 110 volts.
Fuse: 30 amps.

PERFORMANCE TESTS

Method I (Started and kept at "low" heat to dryness)

Material	Volume	Container	Covered or open	Max. temp. reached	Time required for evap.	Boiling, spattering, bumping
1:1 H_2SO_4	25 ml.	100-ml. beaker	Open	103° C.	....	None
N 5 Extract	25 ml.	100-ml. beaker	Open	77° C.	2 hr. 10 min.	None
N 5 Extract	25 ml.	100-ml. beaker	Covered	87° C.	....	None
Distilled water	25 ml.	100-ml. beaker	Open	77° C.	2 hr.	None
Distilled water	25 ml.	100-ml. beaker	Covered	87° C.	....	None

Method II (Started and left on "high" for 30 minutes, then turned to "low")

Material	Volume	Container	Covered or open	Initial temp.	Temperature reached in 30 min.	Time required for evap.	Boiling, spattering, bumping
Silica sand	25 ml. (40 gm.)	100-ml. beaker	Open	24° C.	152.5° C.	....	None
1:1 H_2SO_4	25 ml.	100-ml. beaker	Open	25° C.	114.5° C.	....	None
N 5 Extract	25 ml.	100-ml. beaker	Open	26.5° C.	93.5° C.	1 hr. 15 min.	None
N 5 Extract	25 ml.	100-ml. beaker	Covered	23° C.	102° C.	....	Boils
N/2 HCl Extract	10 ml.	50-ml. beaker	Open	....	....	55 min.	None

Rapid Chemical Methods Assemblies

The full complement of R.C.M. determinations includes:

1. Calcium in cane juice.
2. Nitrogen in cane juice.
3. Phosphate in cane juice.
4. Potash in cane juice.
5. Calcium in filter cake.
6. Total nitrogen in filter cake.
7. Phosphate in filter cake.
8. Total nitrogen in cane leaves.
9. Potash and phosphate in cane leaves.
10. Potash and phosphate in mill ash.
11. Calcium in molasses.
12. Total nitrogen in molasses.

13. Potash in molasses.
14. Calcium in soil.
15. Lime requirement in soil.
16. Replaceable magnesium in soil.
17. Total nitrogen in soil.
18. Available nitrogen in soil.
19. Phosphate in soil.
20. Phosphate in soils high in calcium and other carbonates.
21. Soil phosphate fixation.
22. Potash in soil.
23. Potash in soils high in calcium.
24. Soil reaction (pH).
25. Magnesium in water.
26. Nitrogen in water.
27. Phosphate in boiler water.
28. Total chlorides (salt) in irrigation and other waters.
29. Potash in water.
30. Calcium in water.
31. Potash in soil where low concentrations of the nutrient prevail.

Summary

This contribution supplements a previous article (2) describing rapid chemical methods of analysis which are applicable to agricultural-chemical studies of soils, waters, plant materials, and mill by-products.

A discussion is presented which deals with the application, preparation, use and care of durable color standards for rapid colorimetric analyses.

Included in this paper are descriptive details for the rapid determination of phosphate and potash in soils which carry large amounts of calcium and other carbonates. Other determinations include calcium in cane juice, lime requirement in soils, replaceable magnesium in soils, magnesium in water, total chlorides (salt) in water, calcium in water, and total nitrogen, potash, and phosphate in cane plant leaves.

Important features of a modern laboratory are described and specifications are offered which may be used in the construction of a suitable laboratory.

Bibliography

(1) Denny, F. E., 1927. Field Method for Determining the Saltiness of Brackish Water. Ecology, 8: 106-112.

(2) Hance, F. E., 1936. Soil and Plant Material Analyses by Rapid Chemical Methods. The Hawaiian Planters' Record, 40: 189-299.

Views of R.C.M. Laboratories.

Waiakea Mill Company, Hilo, Hawaii. G. G. Richardson, Agriculturist.

Views of R.C.M. Laboratories.

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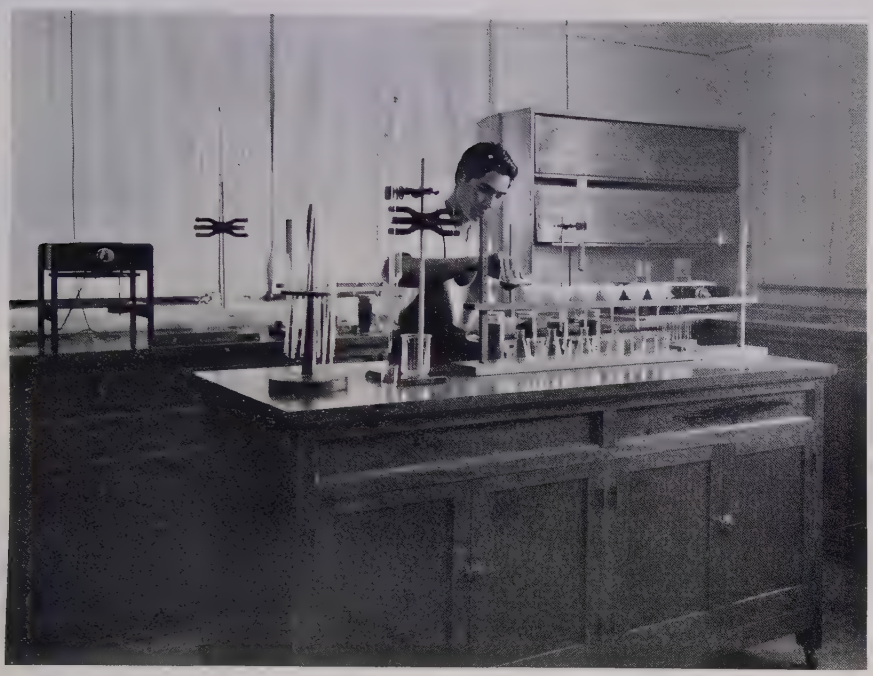

Views of R.C.M. Laboratories.

Maui Agricultural Company, Ltd., Paia, Maui. A. D. Waterhouse, Agriculturist.

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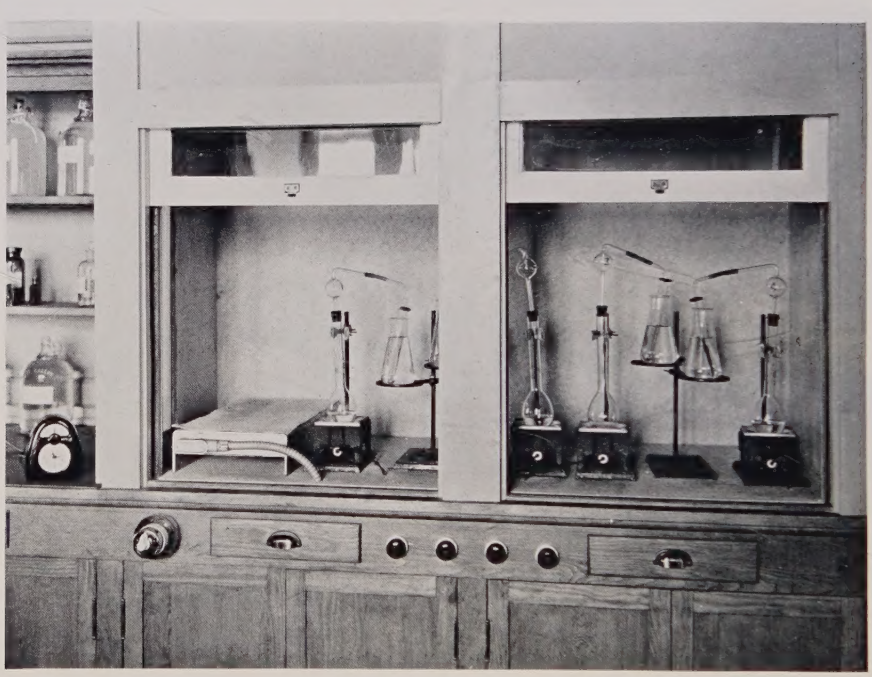
Maui Agricultural Company, Ltd., Paia, Maui. A. D. Waterhouse, Agriculturist.

Views of R.C.M. Laboratories.

Pioneer Mill Company, Ltd., Lahaina, Maui. H. J. W. Taylor, Agriculturist.



Views of R.C.M. Laboratories.

Pioneer Mill Company, Ltd., Lahaina, Maui. H. J. W. Taylor, Agriculturist.

Sugar Prices

96° CENTRIFUGALS FOR THE PERIOD
DECEMBER 24, 1936, TO MARCH 15, 1937.

Date	Per Pound	Per Ton	Remarks
Dec. 24, 1936	3.80¢	$76.00	Puerto Ricos.
" 28	3.90	78.00	Cubas.
" 30	3.905	78.10	Puerto Ricos, 3.90; Cubas, 3.91.
Jan. 4, 1937	3.96	79.20	Cubas.
" 7	3.91	78.20	Cubas.
" 12	3.90	78.00	Puerto Ricos.
" 15	3.81	76.20	Cubas.
Feb. 1	3.68	73.60	Puerto Ricos.
" 2	3.65	73.00	Puerto Ricos.
" 5	3.61	72.20	Cubas.
" 19	3.50	70.00	Puerto Ricos.
" 24	3.45	69.00	Puerto Ricos.
Mar. 2	3.48	69.60	Puerto Ricos.
" 5	3.60	72.00	Puerto Ricos.
" 8	3.57	71.40	Puerto Ricos.
" 9	3.55	71.00	Philippines.
" 15	3.50	70.00	Cubas.